INTRODUCTION

Gaṇeśa Daivajña and *Grahalāghavam*

In this work, we have provided an English Exposition - with explanatory notes, derivations and worked examples - of the popular Sanskrit *karaṇa* text, *Grahalāghavam* . The author of this handbook of Indian astronomy is Gaṇeśa Daivajña who belonged to the early 16th century.

There is a general belief that after Bhāskara II there was a decline in the development of mathematics and astronomy in India. While there may be some truth in this belief, thanks to historical reasons, it is also true that the post - Bhāskara period saw an intensely creative activity in mathematics in the regions south of the Vindhyas. In fact Kerala became the cradle of tremendous and rich mathematical output - often anticipating developments in the European mathematics. In other parts of India too there shone great luminaries, like Gaṇeśa Daivajña, upholding the great tradition of Indian astronomy and mathematics.

In fact, the astronomical works of no other astronomer are in use among the makers of traditional *pañcāṅgas* (astronomical almanacs) in most parts of India today as those of the great and popular astronomer, Gaṇeśa Daivajña.

1. Date and place of Gaṇeśa and Keśava Daivajña

Gaṇeśa Daivajña's father was the famous astronomer Keśava Daivajña and his mother's name was Lakṣmī. He was born in 1507 AD (*śaka* 1429) at a place called Nandigrāma on the western sea-coast.

S.B. Dikshit points out that Nandigrāma is at present a village called Nandagaon in the Janjeera State in the Konkan region. It lies about 40 miles to the south of Mumbai (Bombay). The family belonged to the *gotra* (patrilineal ancestry) of *Kuśika*. Gaṇeśa's grand-father (Keśava's father) was Kamalākara, also an eminent astronomer. Gaṇeśa's teacher in astronomy was his father himself while Keśava's *guru* was Vaijanātha.

Gaṇeśa's father, Keśava, composed several works and commentaries on astronomy and astrology among which his astronomical work, *Grahakautuka* was highly respected. In fact, Keśava is regarded as one of the best observational astronomers of ancient and medieval India. In his *Mitākṣarā* auto-commentary on the *Graha kautuka,* Keśava observes:

"The figures as calculated from the *Brahmā, Āryabhaṭa* and *Saura siddhāntas* exhibit a vast difference in the positions of Mercury (Budha) and Venus (Śukra). Saturn (Śani) has shown an excess of five degrees when actually observed in the sky at the time of conjunction with stars and planets and while setting and rising... Similarly, a difference is recorded in epochal positions and in the annual rates of motion....".

"Hence the future calculators should calculate planetary positions by adopting the figures of revolutions increased or decreased in conformity with the actual observed phenomena of conjunctions, rising and setting of stars and planets in their own times. The writer (Keśava) has accordingly found, out the mean position of the Moon, instead of its maximum equation of centre, by reversed steps, from the observation of the lunar eclipse at the ending moment of the fullmoon, since the equation of centre is neither positive nor negative. The Moon's apogee was finally fixed by reversing the steps of calculation, after observing the eclipse at the moment of the fullmoon in the celestial globe of observation since the maximum correction is neither additive nor subtractive. The moon's position was found to be 5 minutes (of arc) less as compared to that calculated from the *Sūryasiddhānta.* The apogee agreed with that of the *Brahmapakṣa* Thus, the writer has calculated the positions of planets by a short method after observing their actual positions at the present time".

2. Works of Gaṇeśa Daivajña

Gaṇeśa composed several important works on astronomy, astrology etc among which his astronomical treatise *Grahalāghavam* is the most famous. In fact, the remarkable popularity of the *Graha*

lāghavam surpassed that of his father's *Grahakautuka* which was truly an important text in its own right.

Gaṇeśa's other works are: *Laghu-* and *Bṛhat-Tithi Cintāmaṇi,* a commentary on Bhāskara's *Siddhānta Śiromaṇi,* a commentary on Bhāskara's *Līlāvaṭī* (called *Buddhivilāsinī). Vivāha vṛndāvana ṭīkā, Muhūrta tattvatīka, Śrāddha nirṇaya* etc. Gaṇeśa himself mentions another work of his, *Parvanirṇaya.*

Among Gaṇeśa's works, the *Grahalāghavam* appears to have been composed first, believed to be when he was just 13 years old. The epoch of the *Grahalāghavam* is March 19, 1520 AD, Monday.

The work, *Laghu tithi cintāmaṇi* was composed in *śaka* 1447 (1525 AD) and the *Buddhivilāsinī* commentary on Bhāskara's *Līlāvatī* in the year 1545 AD. Another work, *Pāta sāraṇī,* was composed some time after 1538 AD.

Gaṇeśa's *Vṛndāvanaṭīkā* gives the date of its composition in a very interesting fashion: "Take 12 as the number for the *samvatsara (hāyan).* Add one *(lava)* for *ayana* to it. Add 6 to the sum of these two numbers (i.e, to 12 + 1) so as to obtain (19) as the number of the *yoga.* Add 4 to the sum which would give 23 as the number of the *nakṣatra* and one *(lava)* for the *pakṣa.* If a *pakṣa* is added to one more *pakṣa* (i.e, 1 + 2), it would give 3 as the number denoting the week day. Take 1 as the *tithi* number and 11 as the month number. Multiply the sum of all these numbers by 21 and increase the product by 9 (*nanda*).The result is the *śaka* year number". This gives us the following:

Samvat	*Ayana*	*Yoga*	*Nakṣ*	*Pakṣa*	*Vāra*	*Tithi*	*Māsa*	*Śaka*
(12	+ 1	+ 19	+ 23	+ 1	+ 3	+ 1	+ 11) x 21 + 9	= 1500

i.e,(71 x 21) + 9 = 1491 + 9 = 1500.

This means that the text, *Vivāha vṛndāvana tikā* was composed on *Māgha* (11th lunar month) *Śukla* (1st *pakṣa) Pratipat* (1st *tithi)* of *śaka* 1500 (i.e., 1578 AD), *Bahudhānya* (12th) *samvatsara,* during *Uttarāyaṇa* (1st *ayana), Dhaniṣṭhā* (23rd) *nakṣatra* and

parigha (19th) *yoga.*

The date of the said text suggests that Gaṇeśa was *about* 71 years old when he composed it. However, Dikshit refers to a manuscript copy of the *Vṛndāvanaṭīkā* which gives the year of its composition as *śaka* 1476 (i.e. 1554 AD), *Ananda samvatsara,* which is 24 years earlier than the above-cited date (1578 AD)

In the *Grahalāghavam,* the positions of planets have been given for the moment of sunrise of Monday, the newmoon day of *Phālguṇa* of *śaka* 1441 corresponding to March 19, 1520 AD (Julian).

3. Special features of *Grahalāghavam*

Gaṇeśa has simplified the method of computations of the positions of planets which is otherwise laborious by the traditional method.

To avoid a huge number for the *ahargaṇa* (number of civil days since the epoch), Gaṇeśa has adopted an *ahargaṇa* cycle of 4016 days, approximately constituting 11 solar years. Therefore, the modified *ahargaṇa,* being the remainder exceeding a completed number of cycles (of 4016 days each), never exceeds 4016 days and is hence handy.

From the point of view of a *pañcāṇga*-maker or a beginner who is ignorant of trigonometry, *Grahalāghavam* is easy to use since Gaṇeśa has completely dispensed with the trigonometric functions.

In fact, the dropping of trigonometric ratios has by no means seriously affected the accuracy of results. Even the other *karaṇa* texts, using the sine tables, generally give the values of sines of angles only in intervals of 15^0 or $3\frac{3}{4}^0$.

Therefore, the sine-values for intermediate angles, by linear interpolation, are only approximate.

4. Popularity of *Grahalāghavam* and its commentators

As mentioned earlier, the *Grahalāghavam* of Gaṇeśa Daivajña is the most popular astronomical text, among the ancient and medieval texts, currently used in most parts of India. Further, among the *karaṇa* works (hand-books) on Indian astronomy, the *Grahalāghavam* is considered as the most comprehensive, exhaustive and easy to use text.

The *Grahalāghavam* carries with it very useful and authoritative commentaries by reputed astronomers like Gaṅgādhara (1586 A.D.), Mallāri (1602 A.D.) and Viśvanātha (around 1612 A.D.)

Gaṅgādhara's commentary on the *Grahalāghavam* is called *Manoramā*. His father was Nārāyaṇa who authored *Muhūrta mārtāṇḍa*. Gaṅgādhara was a Vājasaneyī Brāhmin belonging to the *Kauśikagotra,* the same as that of Gaṇeśa Daivajña. Gaṅgādhara lived in a village called Tapar, lying to the north of *Ghṛṣṇeśvara* (Lord Śiva) temple which is to the north of Devagiri (Daulatabad).

Viśvanātha was brother of the highly accomplished astronomer Viṣṇu who composed a *karaṇa* with the epochal year 1608 AD This *karaṇa* text is based on the *Sūrya siddhānta.* Viṣṇu also wrote a commentary on Gaṇeśa Daivajña's *Bṛhat tithi cintām aṇi* in which he explains the theory also. Viśvanātha has written an *udaharaṇa* on his brother's *karaṇa.*

The two popular commentators of *Grahalāghavam* are Viśvanātha and Mallāri. They were born in illustrious Mahārāstrian Brāhmin families of astronomers. Mallāri's father was Divākara, a pupil of Gaṇeśa. Kamalākara, author of the *Siddhānta tattva viveka* and Raṅgaṇātha who wrote a commentary on the *Sūryasiddhānta* were descendants of Viśvanātha and Mallāri. Nṛsiṃha, nephew and pupil of Gaṇeśa, wrote his commentary *Harṣakaumudī* in 1548. The other commentators are Gaṅgādhara (1586), Nārāyaṇa (Kaśī, before 1635) and Kamalākara (before 1662).

Viśvanātha has given a large number of examples in his commentary to illustrate the methods of the *Grahalāghavam*. The *Graha lāghavam* is extensively used by the *pañcāṅga*-makers particularly in Maharashtra, Gujarat, northern parts of Karnataka, the Hyderabad Deccan region of Andhra Pradesh and by the Deccanis of Varanasi, Gwalior and Indore. It is pointed out that even the government almanacs published at Indore and Gwalior used the *Grahalāghavam* and the *Tithicintāmaṇi* of Gaṇeśa Daivajña.

5. Some special results of Gaṇeśa Daivajña

(i) Phase of the Moon

From the newmoon to the fullmoon, the *phase* of the Moon increases, given by

$$\text{phase} = (1 + \cos d)/2$$

where d is the elongation $S\hat{M}E$ of the earth from the Sun as seen from the Moon. In fact, we have $d = 180^\circ - E$, so that

$$phase = (1 - \cos E) / 2$$

where E is the elongation of the Moon from the Sun as seen from the earth. On a newmoon day, $E = 0^\circ$ so that the phase of the Moon is zero. On a fullmoon day, $E = 180^\circ$ so that the phase of the Moon is one.

In Indian astronomy, the phase of the Moon is measured by the width of the illuminated part of the Moon which is called *sita* (or *śukla*). The width of the unilluminated part, equal to the difference between the Moon's diameter and the *sita* is called *asita*. In fact,

$$sita = \frac{(M - S) \times (Moon's\ \ ang.\ diameter)}{180}$$

where M and S denote the celestial longitudes of the Moon and the Sun respectively in degrees.

Gaṇeśa Daivajña gives the formula

$$sita = \left(1 - \frac{1}{5}\right)T$$

aṅgulas where T is the number of *tithis* elapsed in the bright fortnight *(śukla pakṣa)* and the Moon's diameter is taken as 12 *aṅgulas*. Of course, this formula is approximate and a similar formula is given by Brahmagupta.

(ii) Rationale for four sides to form trapezium

Bhāskara II investigates the possibility of four sides forming a trapezium. He gives the condition: "in a trapezium the sum of the other flank side and the face is smaller than the sum of the smaller flank side and the base". *(Līlāvatī*, 185)

Gaṇeśa Daivajña has provided a rationale for this statement of Bhāskara II.

(iii) Proof of the *Śulva theorem* (Pythagoras' theorem)

Gaṇeśa Daivajña in his *Buddhivilāsinī* commentary on the *Līlāvatī* provides a fully geometrical proof for the geometrico-algebraic rationale provided by Bhāskara II for the so-called Pythagoras' theorem on a right-angled triangle.

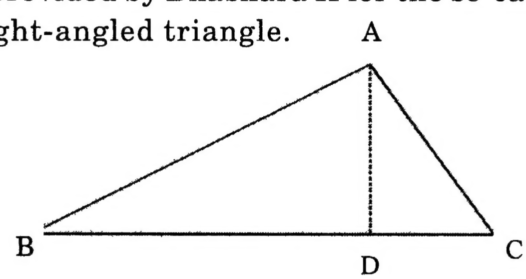

Fig.1: Proof of the Śulva theorem

Let ABC be a triangle right-angled at A (Fig 1). Let AD be the perpendicular to BC. Then the triangles ADB, CDA and CAB (the vertices are in the order of correspondence of equal angles) are *similar*. Therefore, from triangles ADB and CAB, we have

$$\frac{AB}{BC} = \frac{BD}{AB} \text{ or } BD = \frac{AB^2}{BC} \qquad .....(1)$$

Similarly, from triangles *CDA* and *CAB,*

$$DC = \frac{AC^2}{BC} \qquad .....(2)$$

From (1) and (2), we get

$$BD + DC = BC = \frac{AB^2 + AC^2}{BC}$$

or

$BC^2 = AB^2 + AC^2$

(iv) Construction of rational quadrilaterals

Gaṇeśa Daivajña, commenting on the method of Brahmagupta to obtain a quadrilateral with rational sides, says that four rational right-angled traingles *(jātyas)* are to be formed out of two basic rational right triangles as follows:

If $m^2 - n^2$, $2mn$, $m^2 + n^2$ and $p^2 - q^2$, $2pq$, $p^2 + q^2$

are the sides of two rational right triangles, then according to Gaṇeśa, the following are the traingles out of which the quadrilaterals are built up :

(i) $(m^2 - n^2)(p^2 - q^2)$, $2mn\,(p^2 - q^2)$, $(p^2 - q^2)(m^2 + n^2)$

(ii) $(m^2 - n^2)(2pq)$, $4mnpq$, $2pq\,(m^2 + n^2)$

(iii) $(p^2 - q^2)(m^2 - n^2)$, $2pq\,(m^2 - n^2)$, $(p^2 + q^2)(m^2 - n^2)$

(iv) $(p^2 - q^2)\,2mn$, $4pqmn$, $(p^2 + q^2)(2mn)$

However, T.A. Sarasvati Amma wonders whether this is the procedure intended by Brahmagupta and Bhāskara II.

(v) Evaluation of π

Āryabhaṭa (b. 476 AD) has given the value of π as

$$\pi = \frac{62832}{20000} = 3.1416$$

and he points out that this value is approximate *(asanna).*

Bhāskara II also gives the value

$$\pi = \frac{3927}{1250} = 3.1416 \text{ and } \pi = \frac{355}{113} = 3.1415929$$

the former value being the same as the one given by Āryabhaṭa (obtained by removing the common factor 16 in the ratio).

The mode of arriving at this value of π is by considering the perimeter of a regular polygon inscribed in a circle. The ratio of the perimeter of the polygon to the diameter of the circle approximates the constant π. Of course, the more the sides of the polygon, the better is the approximation.

Gaṇeśa Daivajña suggests that the number of sides of the inscribed polygon, starting from 12, is successively doubled as 24, 48 until it is 384. The diameter of the circle is taken as 100 units. Then the ratio of the perimeter of the 384-sided polygon inscribed in a circle of diameter 100 would give the approximate value of π as 3927/1250.

Gaṇeśa's commentary, *Buddhivilāsinī on* the *Līlāvatī,* is an extremely useful text to understand the rationales for the formulae and methods used by Bhāskara II and his predecessors.

6. *Grahalāghavam (GL)*

In our present work, for each *śloka* we have given a working English translation along with mathematical explanation, derivations, worked examples, tables and diagrams wherever necessary. This work is based on the printed edition of *GL,* with commentaries

of Mallāri and Viśvanātha, edited by Pt. Kedaranath Joshi and published by Motilal Banarsidass, Varanasi, 1981.

The text of *Grahalāghavam* consists of 187 *ślokas* distributed into 14 chapters. However, the commentaries of Mallāri and Viśvanātha contain a fifteenth chapter of 15 *ślokas* called *Pañcāṅga candragrahaṇa*. The text seems to have undergone quite a few changes in the hands of descendants and commentators. However, the popularity of the *Grahalāghavam* remains unchallenged. The mean positions of the Sun, the Moon and the five *tārāgrahas* viz. Kuja, Budha, Guru, Śukra and Śani are computed in Chapter 1. The epoch adopted by Gaṇeśa Daivajña is March 19, 1520 AD (J), Monday, at the mean sunrise at Ujjayinī. We have provided derivations for the formulae of the text using the basic data of the numbers of revolutions *(bhagaṇas)*, of the heavenly bodies in the course of a *Mahāyuga* of 432 x 10^4 years.

The true positions of the Sun and the Moon using their equations of centre *(Mandaphalam)* are worked out in the *Śpaṣṭādhikāra* (Chapter 2). The approximation for the *Mandaphalam* used by Gaṇeśa avoiding the trigonometric ratios is adequately explained. In fact, this justified device has greatly simplified computations.

In Chapter 3 computations of the true positions of the five star-planets are worked out by applying the two important equations namely *Mandaphalam* and *Śīghraphalam*. While the first equation corresponds to the "equation of centre" due to the eccentricities of orbits, the second one corresponds to converting the heliocentric positions to the geocentric. We have demonstrated the procedures of the text with worked examples - one relevant to the time of the commentator Viśvanātha (early 16th Cent). The second example is for a modern date.

In the *Tripraśnādhikāra* (Chapter 4) the problems of *dik, deśa* and *kāla* i.e., direction, place and time are discussed. While the mathematical expressions involve the trigonometric ratios *jyā* and *koṭijyā*, the greatness of the text lies in providing justified approxi-

mations by avoiding these trigonometric ratios. The prupose of this exercise is mainly to simplify the computations for the benefit of the *Pañcāṅga* makers and lay students.

This intended purpose is amply served. The important parameters of *krānti* (declination), *akṣāṃśa* (latitude of a place), *lagna* (ascendant), *palabhā* (shadow of the gnomon, *śaṅku)* etc. are explained with examples.

The Lunar and Solar eclipses are studied in Chapters 5 and 6. In these chapters computations of the circumstances of the two types of eclipses are explained. The determinations of the *sparśa* (beginning), *madhya* (middle) and *mokṣa* (end) of an ordinary eclipse and of the *sammīlanam* and the *unmīlanam* of a total eclipse *(khagrāsa)* are demonstrated with traditional and modern examples. In the case of solar eclipse, the effects of the parallax on the longitude *(lambanam)* and on the latitude *(nati)* of the Moon are explained.

The speciality of *GL* lies in computing the posibility and circumstances of eclipses without using *ahargaṇa,* through *māsagaṇa* (the number of completed lunar months). This procedure is explained in detail in Chapters 7 and 8. We have elucidated the procedures with examples.

In Chapter 9 *(Udayāstādhikāra),* an exhaustive study of the heliacal rising and setting of the planets and their retrograde motion *(vakragati)* etc., using the *śīghrakendra* (the angular distance of a planet from the Sun) is presented.

The shadow-related problems regarding planets and stars and using them to find out directions and elapsed time are explained in Chapters 10 and 11. Finding the *lagna* and the time by observing a star on the meridian is also discussed.

Chapter 12 *(Śṛṅgonnatyadhikāra)* deals with the rising of the Moon's "horns". Finding the *'valanam'* (deflection) is also explained in this chapter.

In Chapter 13, conjunctions of planets *(grahayuti)* is presented for which their angular diameters have to be determined. The method of determining the days elapsed *(gata)* or to be completed *(gamya)* for the occurrence of a conjunction is explained. Similarly, the conjunction of a planet with the Moon (an occultation) can be predicted by determining the *śara* (latitude), which is corrected for its *nati*.

Two important *yogas* between the Sun and the Moon viz., *Vyātīpāta* and called *Vaidhṛtipātas* are discussed in Chapter 14. These occur when the declinations *(krānti)* of the Sun and the Moon have the same magnitude and lie either on the same side or on opposite sides of the celestial equator.

In Chapter 15, obtaining the true positions, diameters etc. of the Sun and the Moon from the count of elapsed lunar months *(māsagaṇa)* is discussed in detail.

In concluding Chapter 16, the author Gaṇeśa explains how to obtain planetary positions etc for the times before his epoch.

At the end of this text, Appendices and a detailed Bibliography are included. The Appendices include tables of *mandaphala* (equation of centre) and the *śīghraphala* of the planets, the list of 27 *yogas*, Bhāskara I's. approximate formula for sine and the *udayamānas* of *rāśis*.

In the course of the text, mathematical derivations, comparison with modern results and illustrative diagrams are provided.

CHAPTER 1

MADHYAMĀDHIKĀRA

(Mean Positions of Planets)

***Śloka* 1** : The invocatory verse has two interpretations :

(a) *Keśava*'s (i.e, *Bāla Mukunda*'s) words viz, the *Vedas* (i.e, *Śrutis*) are supreme. By observing the practices enjoined in the *Vedas* the mind gets purified leading to the *Supreme Knowledge* and which (*Vedas*) have brief, difficult and immutable words implying many meanings which were made simple and clear through the later explanatory works (i.e, *Smṛtis* and commentaries) by the incarnations of Lord *Viṣṇu*. Victory to such words of the Lord !

(b) The author's father's i.e., Keśava's words are glorious. By studying his works the mind becomes clear and absorbs the knowledge of stars and planets. Though the words are brief these are clear in their meanings and further flawless and which are elucidated further by the commentaries of his disciples.

Remarks : Gaṇeśa Daivajña's preceptor and father was Keśava Daivajña who composed a handbook of astronomy called *Grahakautukam*. This text was very popular before his son's work *Grahalāghavam* outshone it.

***Śloka* 2** : O mathematician ! Meditate on that form of *Viśṇu (Rāma's)* which rendered *Śiva's* bow into three pieces and threw it to the ground, who is decorated with the garland of *sattva* quality, who gives life to every living being, who grants the wishes, who has taken the human incarnation, who runs the universe and is very handsome.

(b) O mathematician ! You read this handbook (*karaṇa grantha*) which is devoid of sines and cosines (the trigonometric functions), which is decorated with constant multipliers and divisors (i.e., parameters), which contains operations with angles (like anomaly etc.), which provides proper knowledge of the equation of centre etc., which also adopts the knowledge of shadow of the gnomon (*śaṅku*) and which is mind-capturing and error-free.

***Śloka* 3** : Even though very great scholars composed (astronomical) handbooks, their (mathematical) results are not achieved if sines (and arcs) are left out. Therefore, I (Gaṇeśa) set forth to compose a (planetary) handbook of procedures which are very simple and clear.

Now, the author describes the procedure for finding the *Ahargaṇa* (the number of civil days elapsed since the chosen epoch) :

***Ślokas* 4 and 5** : The procedure described in these two *ślokas* is explained below, for convenience, in a simple algorithmic style.

The epoch chosen by Gaṇeśa Daivajña is *Śālivāhana Śaka Varṣa* (year) 1442 *Caitra śukla pratipat,* corresponding to March 19, 1520 AD (Julian), Monday. The *Ahargaṇa* for a given lunar date is determined as follows:

(i) Subtract 1442 from the *Śālivāhana śaka* year (elapsed) of the given date to get the years elapsed (*gatābdi*).

(ii) Divide the remainder by 11. The quotient is called *cakra* (cycles) $\equiv$ C.

(iii) Multiply the remainder, obtained in step (ii), by 12 and to the product add the number of lunar months elapsed, counting *Caitra* as 1 etc. The sum thus obtained is called 'mean lunar months' (*madhyama māsagaṇa*) denoted by *M.*

(iv) number of *adhikamāsas* is given by the quotient of $\frac{M+2C+10}{33}$

(v) True lunar months (*spaṣṭa māsagaṇa*) = Mean lunar months + *adhikamāsas* = M + Quotient of $\frac{M+2C+10}{33} \equiv TM$

(vi) Mean *ahargaṇa* (*Madhyama ahargaṇa*)

$$MAH = (TM \times 30) + TI + \frac{C}{6}$$

where *TI* is the number of *tithis elapsed* in the given lunar month.

(vii) *Kṣaya dinas* = Quotient of $\left[\frac{1}{64} \text{ } \textit{Madhyama Ahargaṇa}\right] \equiv KD$

(viii) True *ahargaṇa* (*sāvana dinas*) i.e, the number of civil days,

TAH = Mean *ahargaṇa* – *kṣaya dinas*

$= MAH - KD$

$= MAH - \text{Quotient of } \frac{1}{64}\ (MAH)$

(ix) However, since the average values of parameters are considered in the above computations, 1 day may have to be either *added to* or *subtracted from* the result of (viii) to get the actual true *ahargaṇa*.

This is done by verifying the weekday as follows :

(a) Multiply the *cakras* by 5 i.e., find $5C$. Add *sāvana ahargaṇa* to this i.e., find $(5C + TAH)$.

(b) Divide the result of (a) by 7 and find the remainder. Let R = Remainder of $\left\{\frac{5C + TAH}{7}\right\}$. If $R = 0$, then it is Monday; $R = 1$ then it is Tuesday; and so on.

(c) If the calculated weekday is a day next to the actual weekday, then *subtract* 1 from *TAH* and if it is one day less than the actual weekday, then *add* 1 to *TAH*.

[See Note (1) and (2) appearing later].

Example 1 :

Śā.Śaka 1534, *Vaiśākha Pūrṇimā*, Monday ≡ May 16, 1612 A.D. (Gregorian)

(i) Subtract 1442 from 1534 :

Gatābdi = 1534 – 1442 = 92 years (from the epoch)

(ii) Divide the remainder in (i) by 11 :

the quotient, *cakras* = 8 ≡ C and the remainder = 4

(iii) Multiplying the remainder from (ii) i.e, 4 by 12 and adding the number of lunar months elapsed in the given year we get

$(4 \times 12) + 1 = 49 \equiv M$ is the *madhyama māsa gaṇa*

(iv) No. of *Adhikamāsas* = $\dfrac{M+2C+10}{33} = \dfrac{49+2(8)+10}{33} = \dfrac{75}{33}$;

Quotient = 2.

(v) M + No. of *adhikamāsas* = 49 + 2 = 51 = TM is the *spaṣṭa māsagaṇa*

(vi) (a) Mean *ahargaṇa* (*Madhyama ahargaṇa*)

= ($TM \times 30$) + (No. of *tithis* elapsed in the given lunar month)

= $(51 \times 30) + 14 = 1544$

(b) Add INT $\frac{1}{6}[C]$ i.e., INT (8/6) = 1 to the result of (vi) (a)

∴ 1544 + 1 = 1545 ≡ MAH

(**Note** : INT stands for the integer value).

(vii) *Kṣayadinas* = $\text{INT}\left(\dfrac{MAH}{64}\right) = \text{INT}\left(\dfrac{1545}{64}\right) = 24 \equiv KD$

(viii) *Sāvana ahargaṇa* (i.e., No. of civil days in the running *cakra*)

$$= MAH - KD = 1545 - 24 = 1521 \equiv TAH$$

(ix) Week day verification :

$$5C + TAH = 5(8) + 1521 = 1561$$

$$\therefore \quad R = \text{Remainder of } \left\{\frac{1561}{7}\right\} = 0$$

That is, the weekday comes out as Monday.

Since the weekday obtained from calculation is the same as the actual weekday (known), nothing needs to be added to or subracted from *TAH*. Therefore,

True *ahargaṇa* = 1521 No. of *cakras* = 8

Note 1 : Sometimès when (*Śaka* year 1442) is divided by 11, to get *cakras* the remainder could be 0. In that case even 2 may have to be added to or subtracted from the obtained *sāvana dinas* to get the true *ahargana* for the weekday. See the following example.

Example 2 : *Śaka* 1574 *Caitra Śukla Pratipat Ravivāra* (i.e, April 7, 1652 A.D., Sunday)

(i) *Gatābdi* = 1574 – 1442 = 132, years since the epoch.

(ii) $C = \text{INT}\left(\dfrac{132}{11}\right) = 12$ Remainder of $\left(\dfrac{132}{11}\right)$ is 0.

(iii) $(0 \times 12) + 0 = 0 \equiv M.$

(iv) Number of *adhikamāsas* $= \text{INT}\left[\frac{M + 2C + 10}{33}\right] = \text{INT}\left[\frac{0 + 24 + 10}{33}\right]$

i.e, *adhikamāsas* $= \text{INT}\left[\frac{34}{33}\right] = 1$

(v) $TM = M$ + No. of *adhikamāsas* = 0 + 1 = 1

(vi) *Mean ahargaṇa* : $MAH = (1 \times 30) + 0 + \text{INT}\,[\frac{1}{6}\ (12)] = 30 + 2$ = 32.

(vii) *Kṣaya dinas*, $KD = \text{INT}\left(\frac{MAH}{64}\right) = \text{INT}\left\{\frac{32}{64}\right\} = 0$

(viii) *Sāvana ahargaṇa* = $MAH - KD$ = 32 – 0 = 32

$\therefore$ *Cakras* = 12, *Ahargaṇa* = 32 (in the running *cakra*)

(ix) Weekday verification : R = Remainder of $\left(\frac{5C + TAH}{7}\right)$

i.e., remainder of $\left(\frac{92}{7}\right)$ or $R = 1$

i.e., Tuesday. But the actual weedkay is Sunday.

Therefore subtracting 2 from the *sāvana ahargaṇa* we get

Actual *ahargaṇa* = 32 – 2 = 30.

Thus, *cakras* = 12 and *ahargaṇa* = 30.

(x) Christian date :

No. of civil days since epoch = (*cakras* $\times$ 4016) + *ahargaṇa*

= 12 (4016) + 30 = 48,222

Kali ahargaṇa of the GL epoch = 16,87,850 (fixed)

Kali Ahargaṇa of the given date : 17,36,072

From Tables 1.1 to 1.3, we have

1600 A.D. (G)	:	17,16,982 (under *kali Ahargaṇa*)
Year 52	:	18,993
April 7	:	97
Total	:	**17,36,072**

corresponding to April 7, 1652 AD (G)

Note 2 : Sometimes there could be an *adhikamāsa* in a particular given lunar year.

(i) If the given date is before the *adhikamāsa* of that lunar year, then subtract 1 from the number of *adhikamāsas* obtained in the calculation.

(ii) If the given date is after the *adhikamāsa* of that lunar year, then add 1 to the number of *adhikamāsas* obtained in the calculation.

This is demonstrated in the following example.

Example 3 :

Śaka 1555 *Caitra Śukla Pratipat*, Friday [March 11, 1633]. In this year *Vaiśākha* is the *adhikamāsa* which comes after the given date.

We shall find the *cakra* and *ahargaṇa* for the given date :

(i) *Gatābdi* : 1555 – 1442 = 113

(ii) *Cakras*, $C = \text{INT}\left(\frac{113}{11}\right) = 10$, Remainder = 3

(iii) Mean *māsagaṇa* = (Remainder × 12) + No. of elapsed lunar months = (3 × 12) + 0 = 36 ≡ *M*

(iv) No. of *adhikamāsas*

$$= \text{INT}\left[\frac{M + 2C + 10}{33}\right] = \text{INT}\left[\frac{36 + 2(10) + 10}{33}\right]$$

$$= \text{INT}\left[\frac{66}{33}\right] = 2 \quad \text{(Note : Remainder = 0)}$$

Since the given date falls before the *adhika Vaiśākha māsa*, subtract 1 from the number obtained above. Therefore, the actual *adhikamāsas* elapsed = 2 – 1 = 1.

(v) True lunar months = *M* + No. of *adhikamāsas* = 36 + 1 = 37 ≡ *TM*

(vi) Mean *Ahargaṇa*, *MAH* = (37 × 30) + *Tithis* elapsed

$$+ \text{INT}\left(\frac{C}{6}\right) = 1110 + 0 + \text{INT}\left(\frac{10}{6}\right) = 1110 + 1 = 1111.$$

(vii) *Kṣayadinas*, $KD = \text{INT}\left[\frac{MAH}{64}\right] = \text{INT}\left[\frac{1111}{64}\right] = 17$

(viii) *Sāvana ahargaṇa* = *MAH* – *KD* = 1111 – 17 = 1094 ≡ *TAH*

(ix) Weekday verification :

$$5C + TAH = 5\,(10) + 1094 = 1144\,;\ \text{Remainder of}\left[\frac{1144}{7}\right] = 3$$

i.e., Thursday; but the actual weekday : Friday

Therefore, the true *ahargaṇa* = *TAH* + 1 = 1095

(x) Christian date : No. of civil days since epoch

= 10 (4016) + 1095 = 41,255

Kali ahargaṇa of the *GL* epoch : 16,87,850

∴ *Kali ahargaṇa* of the date : 17,29,105

From Table 1.1 to 1.3 under *kali ahargaṇa* we have

1600 AD(G)	:	17,16,982
33	:	12,053
March 11	:	70
Total	:	**17,29,105**

corresponding to March 11, 1633 A.D. (Gregorian).

Example 4 : *Śaka* 1530 (*Bhādrapada* is *adhikamāsa*) *Kārtika Śukla Pratipat*, Saturday. We have

(i) *Gatābdi* = 1530 − 1442 = 88

(ii) *Cakra*, $C = \text{INT}\left(\frac{88}{11}\right) = 8$, Remainder = 0

(iii) Mean lunar months $M = (0 \times 12) + 7 = 7$.

(iv) No. of *Adhikamāsas*

$$= \text{INT}\left[\frac{M+2C+10}{33}\right] = \text{INT}\left[\frac{7+16+10}{33}\right] = 1$$

Remainder = 0

Since *Kārtika* month (i.e, the given month) occurs after the *adhika Bhādrapada māsa*, add 1 to the calculated number of

adhikamāsas. Therefore, number of *adhikamāsas* = 1 + 1 = 2.

(v) True lunar months $TM = M$ + No. of *adhikamāsas* = 7 + 2 = 9

(vi) Mean *ahargaṇa* :

MAH = ($TM \times 30$) + (*Tithis* elapsed in the given month)

$$+ \text{INT}\left(\frac{C}{6}\right) = (9 \times 30) + 0 + \text{INT}\left(\frac{8}{6}\right) = 271$$

(vii) *Kṣaya dinas* = $\text{INT}\left(\frac{271}{64}\right) = 4 \equiv KD$

(viii) *Sāvana ahargaṇa* $TAH = MAH - KD = 271 - 4 = 267$

(ix) Weekday verification : $5C + TAH = 40 + 267 = 307$

Remainder of $\left(\frac{307}{7}\right) = 6$ i.e., Sunday.

But the given weekday is Saturday

$\therefore$ True *ahargaṇa* = $TAH - 1 = 266$

(x) Christian date :

No. of civil days since epoch = 8 (4016) + 266 = 32,394

Kali ahargaṇa of *GL* epoch : 16,87,850.

$\therefore$ *Kali ahargaṇa* of the given date : 17,20,244

From Tables 1.1 to 1.3 we have

1600 A.D.	:	17,16,982
Year 08	:	2,922
December 6	:	340
Total	:	**17,20,244**

corresponding to December 6,1608 AD (Gregorian).

Finding the Christian date from the *ahargaṇa* and vice versa

In the above examples we saw how to get the *cakras* and the *ahargaṇa* from the given *Cāndramāna* (i.e, lunar) date. Now, we shall see

how from the thus obtained *cakras* and *ahargaṇa* the corresponding Christian date can be obtained.

In Table 1.1 the *Julian days* and the *ahargaṇas* for the epochs of the *Kaliyuga* and the *Graha lāghavam* are given for the beginnings of the Christian centuries from – 3200 (Julian) to 2200 AD (Gregorian).

Epochs chosen :

(i) The epoch adopted for the *Kali* era is the mean midnight between February 18th and 19th of 3102 BC (i.e, the year –3101).

For any year before Christ (BC), for mathematical convenience, the negative sign is prefixed to 1 less than the numerical value of the Christian year. For example, 46 BC is considered as –45 and 3102 BC as –3101.

This convention is adopted since 1 BC is taken as the "0" year of the Christian era.

(ii) The epoch of the *Graha lāghavam* (*GL*) : *Ganeśa Daivajña* in his *GL* has adopted the mean sunrise (at *Ujjayinī*) of March 19, 1520 (Julian) AD, Monday as the epoch.

(iii) *Julian days* (*JD*) : The reckoning of the Julian days starts from the mean noon (*GMT*) on January 1, 4713 BC, Monday. On that day, at the mean noon (*GMT*), *JD* = 0.

The procedure for finding the Christian date from the *cakras* and the *ahargaṇa* :

(i) Multiply the number of *cakras* C by 4016 (i.e, the number of days in a *cakra*) i.e., find 4016 C. To this 4016 C add the *ahargaṇa* A i.e, find (4016 $C + A$). The *Kali ahargaṇa* for the *GL* epoch is 16,87,850. Add this constant to (4016 $C + A$) i.e, find (4016 $C + A$ + 16,87,850). This gives the *Kali ahargaṇa* for the required date.

From Tables 1.1 to 1.3, for the thus obtained *Kali ahargaṇa* the corresponding Christian date can be obtained as shown in the following example.

Finding the weekday from the *GL ahargaṇa*

Let C and A respectively be the *cakras* and the *ahargaṇa* according to *GL*. Multiply C by 5 and to this product add A i.e., find $(5C + A)$.

Dividing $(5C + A)$ by 7, let the remainder be R. If $R = 0$, then the given date falls on a Monday; if $R = 1$, Tuesday etc.

Example : In the example considered above, $C = 8$, and $A = 1521$. Therefore, $5C + A = 5\ (8) + 1521 = 1561$. When 1561 is divided by 7, the remainder $R = 0$. Therefore, the given date is a Monday.

Finding the *ahargaṇa* from the Christian date :

In Table 1.1, for the beginning of the Christian century (column 1) in which the given date lies – *Kali ahargaṇa* (column 3) and the *cakras* and the (balance) *ahargaṇa* according to *GL* are given in columns 4 and 5. For example, consider October 7th of the year 2001 AD. For this year the century beginning year 2000 (G). From Table 1.1 to 1.3, we have

	Kali ahar.	*GL ahargaṇa*		Julian days
		Ca.	*ahar.*	
2000 (G)	18,63,079	43	2541	24,51,545
Year 1	365	0	365	365
October 7	280	0	280	280
	18,63,724	43	3,186	24,52,190

Weekday from *GL ahargaṇa* : Here $C = 43$ and $A = 3186$.

$\therefore\ 5C + A = 215 + 3186 = 3401$

Dividing $(5C + A)$ by 7, remainder $R = 6$, we get Sunday

Note : In Table 1.1, column 2 gives the Julian days (*JD*). To find the weekday from *JD* of the given date, divide *JD* by 7 and let R be the remainder. If $R = 0$, it is Monday; if $R = 1$, Tuesday etc.

Table 1.1 : *JD, Kali* and *Graha Lāghavam Ahargaṇas*

Chris. Year	Julian Days	*Kali Ahargaṇa*	*Graha Cakras*	*Lāghavam Ahargaṇa*
–3200 (J)	552258	–36208	–430	2822
–3100 (J)	588783	317	–421	3203
–3000 (J)	625308	36842	–412	3584
–2900 (J)	661833	73367	–403	3965
–2800 (J)	698358	109892	–393	330
–2700 (J)	734883	146417	–384	711
–2600 (J)	771408	182942	–375	1092
–2500 (J)	807933	219467	–366	1473
–2400 (J)	844458	255992	–357	1854
–2300 (J)	880983	292517	–348	2235
–2200(J)	917508	329042	–339	2616
–2100 (J)	954033	365567	–330	2997
–2000 (J)	990558	402092	–321	3378
–1900 (J)	1027083	438617	–312	3759
–1800 (J)	1063608	475142	–302	124
–1700 (J)	1100133	511667	–293	505
–1600 (J)	1136658	548192	–284	886
–1500 (J)	1173183	584717	–275	1267
–1400 (J)	1209708	621242	–266	1648
–1300 (J)	1246233	657767	–257	2029
–1200 (J)	1282758	694292	–248	2410
–1100 (J)	1319283	730817	–239	2791
–1000 (J)	1355808	767342	–230	3172
–900 (J)	1392333	803867	–221	3553
–800 (J)	1428858	840392	–212	3934
–700 (J)	1465383	876917	–202	299
–600 (J)	1501908	913442	–193	680
–500 (J)	1538433	949967	–184	1061

(Contd...)

Table 1.1 (Contd.)

Chris. Year	**Julian Days**	***Kali Ahargaṇa***	***Graha Ca.***	***Lāghavam Ahargaṇa***
–400 (J)	1574958	986492	–175	1442
–300 (J)	1611483	1023017	–166	1823
–200 (J)	1648008	1059542	–157	2204
–100 (J)	1684533	1096067	–148	2585
0 (J)	1721058	1132592	–139	2966
100 (J)	1757583	1169117	–130	3347
200 (J)	1794108	1205642	–121	3728
300 (J)	1830633	1242167	–111	93
400 (J)	1867158	1278692	–102	474
500 (J)	1903683	1315217	–93	855
600 (J)	1940208	1351742	–84	1236
700 (J)	1976733	1388267	–75	1617
800 (J)	2013258	1424792	–66	1998
900 (J)	2049783	1461317	–57	2379
1000 (J)	2086308	1497842	–48	2760
1100 (J)	2122833	1534367	–39	3141
1200 (J)	2159358	1570892	–30	3522
1300 (J)	2195883	1607417	–21	3903
1400 (J)	2232408	1643942	–11	268
1500 (J)	2268933	1680467	–2	649
1500 (G)	2268923	1680457	–2	639
1600 (G)	2305448	1716982	7	1020
1700 (G)	2341972	1753506	16	1400
1800 (G)	2378496	1790030	25	1780
1900 (G)	2415020	1826554	34	2160
2000 (G)	2451545	1863079	43	2541
2100 (G)	2488069	1899603	52	2921
2200 (G)	2524593	1936127	61	3301

Table 1.2 : *Ahargaṇa* for Year Beginnings

Year	Days	*Graha Ca.*	*Lāghavam Ahar.*	Year	Days	*Graha Ca.*	*Lāghavam Ahar.*
0	0	0	0	28	10227	2	2195
1	365	0	365	29	10592	2	2560
2	730	0	730	30	10957	2	2925
3	1095	0	1095	31	11322	2	3290
4	1461	0	1461	32	11688	3	3656
5	1826	0	1826	33	12053	3	5
6	2191	0	2191	34	12418	3	370
7	2556	0	2556	35	12783	3	735
8	2922	0	2922	36	13149	3	1101
9	3287	0	3287	37	13514	3	1466
10	3652	0	3652	38	13879	3	1831
11	4017	1	1	39	14244	3	2196
12	4383	1	367	40	14610	3	2562
13	4748	1	732	41	14975	3	2927
14	5113	1	1097	42	15340	3	3292
15	5478	1	1462	43	15705	3	3657
16	5844	1	1828	44	16071	4	7
17	6209	1	2193	45	16436	4	372
18	6574	1	2558	46	16801	4	737
19	6939	1	2923	47	17166	4	1102
20	7305	1	3289	48	17532	4	1468
21	7670	1	3654	49	17897	4	1833
22	8035	2	3	50	18262	4	2198
23	8400	2	368	51	18627	4	2563
24	8766	2	734	52	18993	4	2929
25	9131	2	1099	53	19358	4	3294
26	9496	2	1464	54	19723	4	3659
27	9861	2	1829	55	20088	5	8

(Contd...)

Table 1.2 (Contd.)

Year	Days	Graha Ca.	Lāghava Ahar.	Year	Days	Graha Ca.	Laghava Ahar.
56	20454	5	374	78	28489	7	377
57	20819	5	739	79	28854	7	742
58	21184	5	1104	80	29220	7	1108
59	21549	5	1469	81	29585	7	1473
60	21915	5	1835	82	29950	7	1838
61	22280	5	2200	83	30315	7	2203
62	22645	5	2565	84	30681	7	2569
63	23010	5	2930	85	31046	7	2934
64	23376	5	3296	86	31411	7	3299
65	23741	5	3661	87	31776	7	3664
66	24106	6	10	88	32142	8	14
67	24471	6	375	89	32507	8	379
68	24837	6	741	90	32872	8	744
69	25202	6	1106	91	33237	8	1109
70	25567	6	1471	92	33603	8	1475
71	25932	6	1836	93	33968	8	1840
72	26298	6	2202	94	34333	8	2205
73	26663	6	2567	95	34698	8	2570
74	27028	6	2932	96	35064	8	2936
75	27393	6	3297	97	35429	8	3301
76	27759	6	3663	98	35794	8	3666
77	28124	7	12	99	36159	9	15

Note : (1) In Table 1.3, the first two columns are headed by C and B which stand respectively for a *common* (non leap) year and *bissextile* (leap) year.

For a given date in a leap year, only for January and February, the column headed by B must be used. For other months even in a leap year and for all months in a common year the first column under C must be used.

(2) In Table 1.1, the letters J and G in brackets represent respectively the *Julian* and the *Gregorian* calendars.

Table 1.3 : *Ahargaṇa* for Days of a Year

Dates C	Dates B	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
0	1	0	31	-	-	-	-	-	-	-	-	-	-
1	2	1	32	60	91	121	152	182	213	244	274	305	335
2	3	2	33	61	92	122	153	183	214	245	275	306	336
3	4	3	34	62	93	123	154	184	215	246	276	307	337
4	5	4	35	63	94	124	155	185	216	247	277	308	338
5	6	5	36	64	95	125	156	186	217	248	278	309	339
6	7	6	37	65	96	126	157	187	218	249	279	310	340
7	8	7	38	66	97	127	158	188	219	250	280	311	341
8	9	8	39	67	98	128	159	189	220	251	281	312	342
9	10	9	40	68	99	129	160	190	221	252	282	313	343
10	11	10	41	69	100	130	161	191	222	253	283	314	344
11	12	11	42	70	101	131	162	192	223	254	284	315	345
12	13	12	43	71	102	132	163	193	224	255	285	316	346
13	14	13	44	72	103	133	164	194	225	256	286	317	347
14	15	14	45	73	104	134	165	195	226	257	287	318	348
15	16	15	46	74	105	135	166	196	227	258	288	319	349
16	17	16	47	75	106	136	167	197	228	259	289	320	350
17	18	17	48	76	107	137	168	198	229	260	290	321	351
18	19	18	49	77	108	138	169	199	230	261	291	322	352
19	20	19	50	78	109	139	170	200	231	262	292	323	353
20	21	20	51	79	110	140	171	201	232	263	293	324	354
21	22	21	52	80	111	141	172	202	233	264	294	325	355
22	23	22	53	81	112	142	173	203	234	265	295	326	356
23	24	23	54	82	113	143	174	204	235	266	296	327	357
24	25	24	55	83	114	144	175	205	236	267	297	328	358
25	26	25	56	84	115	145	176	206	237	268	298	329	359
26	27	26	57	85	116	146	177	207	238	269	299	330	360
27	28	27	58	86	117	147	178	208	239	270	300	331	361
28	29	28	59	87	118	148	179	209	240	271	301	332	362
29	30	29	-	88	119	149	180	210	241	272	302	333	363
30	31	30	-	89	120	150	181	211	242	273	303	334	364
31	-	31	-	90	-	151	-	212	243	-	304	-	365

Śloksa 6,7,8 : The dhruvas and ksepakas of all planets

Kṣepaka is the mean position of a heavenly body at the time of the epoch *and dhruvaka* is the multiplier of the completed *cakras* for a given date. In fact, *dhruvaka* is the residual motion of a body in a *cakra* after removing the completed revolutions.

The *dhruvakas* and *kṣepakas* of the heavenly bodies are tabulated below.

Table 1.4 *Dhruvakas* of bodies

	Ravi	Candra	*Cand-rocca*	Rāhu	Kuja	Budha *Kendra*	Guru	Śukra *Kendra*	Śani
Rāśi	0	0	9	7	1	4	0	1	7
Amśa (°)	1	3	2	2	25	3	26	14	15
Kalā (′)	49	46	45	50	32	27	18	2	42
Vikalā(″)	11	11	0	0	0	0	0	0	0

Table 1.5 *Kṣepakas* of bodies

	Ravi	Candra	*Cand-rocca*	Rāhu	Kuja	Budha *Kendra*	Guru	Śukra *Kendra*	Śani
Rāśi	11	11	5	0	10	8	7	7	9
Amśa (°)	19	19	17	27	7	29	2	20	15
Kalā (′)	41	6	33	38	8	33	16	9	21

***Śloka* 9** : The use of *dhruvaka* and *kṣepaka* are explained :

From the motion of a body obtained from the *ahargaṇa* subtract the product of the *dhruvaka* and the *cakra* and to it add the *kṣepaka*. This gives

the mean position of the body for the mean sunrise (at *Laṅkā* and *Ujjayinī*).

In the case of the moon, the distance (in *yojanas*) between one's place and the central meridian (*rekhā*), chosen as the meridian passing through *Laṅkā* and *Ujjayinī*, is divided by 6 to get the correction in *kalās* (minutes of arc). This is added to or subtracted from the earlier obtained position of the moon according as one's place is to the west or to the east of the central meridian (*rekhā*).

Explanation : The above correction described for the moon is referred to as *deśāntara saṃskāra* due to difference in the sunrise timings at the given place and at *Laṅkā*. The *deśāntara* correction for the moon

$$= \frac{\text{The distance in } yojanas}{\text{Circumference of earth in } yojanas} \times \text{Moon's daily motion}$$

Consider the mean daily motion = 790′35″ and *paridhi* (circumference) of the earth = 4967 *yojanas*. We get the *Deśāntara* correction for the moon

$$= \frac{790'35''}{4967} \times (\text{Distance in } Yojanas) = \frac{1}{6.2827} \times (\text{distance in } yojanas)$$

$$\approx \frac{1}{6} \times (\text{distance in } yojanas)$$

where the distance in *yojanas* is the shortest distance of the given place from the meridian passing through *Laṅkā* and *Ujjayinī*. The modern known values of the earth's equatorial and polar radii are respectively 6378.16 km and 6356.775 km. Considering the mean radius of the earth in miles and the circumference of earth given as 4967 *yojanas* in the *GL* commentary, we get 1 *yojana* ≈ 5 miles. The circumference of the earth as 4967 *yojanas* is taken by Bhāskara II in his *Siddhānta Śiromaṇi*.

***Śloka* 10** : The method of calculating the mean longitudes of Ravi, Budha and Śukra has been given in this *śloka* in a systematic manner. It is as follows :

(i) Divide *ahargaṇa* A by 70 and then subtract the quotient from A to get the resultant in degrees.

(ii) Divide A by 150. (The result will be in *kalās*). Divide the result by 60 in order to convert it into degrees.

(iii) Subtract the result of step (ii) from that of step (i).

(iv) Multiply *cakra* $\equiv C$ by *dhruvaka* D and subtract the product from step (iii)

(v) Add *kṣepaka* K to step (iv). The result gives the mean planet in degrees.

i.e., Mean longitude of the planet = $\left\{\left(A - \frac{A}{70} - \frac{A}{150 \times 60}\right) - C \times D\right\} + K$

Note : In traditional Indian astronomy the mean longitudes of Budha and Śukra are taken the same as that of the sun.

Example : For the given date, *samvat* 2036, *śaka* 1901

Phālguṇa śukla pūrṇimā (i.e., 1st March 1979)

$A \equiv$ *Ahargaṇa* $\equiv 3328$, $C \equiv$ *Cakra* $\equiv 41$

$D \equiv$ *Dhruvaka* $= 0^R\ 1^\circ 49'\ 11''$ $K \equiv$ *Kṣepaka* $= 11^R\ 19^\circ\ 41' = 349^\circ 41''$

Mean longitude of the sun = $\left\{\left(A - \frac{A}{70} - \frac{A}{150 \times 60}\right) - C \times D\right\} + K$

$$= \left\{\left(3328 - \frac{3328}{70} - \frac{3328}{150 \times 60}\right) - 41 \times 0^R 1°49'11''\right\} + 11^R 19°41'$$

$= 3555°.1621 =$ **$10^R\, 15°\, 9'\, 43''.6$** [removing completed revolutions].

Note : Step (iii) gives *aharganotpannagraha* (i.e., mean longitude derived from the *ahargaṇa*).

Modern Example :

Given date : 11th August 1998. For the given date, $A = 2033$, $C = 43$.

For the sun, $D = 0^R\ 1°\ 49'\ 11''$ and $K = 349°41''$

$$\text{Mean longitude of the sun} = \left[\left(A - \frac{A}{70} - \frac{A}{150 \times 60}\right) - C \times D\right] + K$$

$$= \left[\left(2033 - \frac{2033}{70} - \frac{2033}{150 \times 60}\right) - 43 \times 1°49'11''\right] + 349°41' = 2275°.1665$$

$=$ **$115°\ 9'\ 59''.5$** [removing completed revolutions].

Another method : Instead of the method explained in *śloka* 10, we can as well adopt the following method in which the *ahargaṇa* is multiplied by the mean daily motion.

In the example considered earlier, $A = 3328$, $C = 41$, $D = 1°49'11''$, $K = 11^R\ 19°\ 41'$ and the mean daily motion of the sun, $m = 59'08''10'''$. [**Note** : Here, $1'' = 60'''$ i.e, one *vikalā* = 60 *prativikalās*]. Therefore, *Ahargaṇa* generated mean longitude $= A \times m$

$= 3328 \times (59'08''10''') = 3328 \times 0°.9856018 = 3280°.083$

$= 40°04'58'' = 1^R\ 10°\ 04'\ 58''$(removing the multiples of revolutions).

Now, $C \times D = 41^\circ \times 1^\circ 49' 11'' = 74^\circ 36' 31'' = 2^R\, 14^\circ\, 36'\, 31''$

$$\therefore \quad (A \times m) - (C \times D) = 1^R\, 10^\circ 04' 58'' - 2^R\, 14^\circ 36' 31''$$

$$= 10^R\, 25^\circ 28' 27''$$

Adding the *Kṣhepaka*, $K = 11^R\ 19^\circ\ 41'$, we get

$$10^R\, 25^\circ 28' 27'' + 11^R 19^\circ 41' = \mathbf{10^R 15^\circ 09' 27''}$$

This is the mean position of the Sun, Budha and Śukra.

Mean position of the Moon

The mean position of the Moon can be determined as follows:

(i) Multiply *ahargaṇa* A by 14 and divide the product by 17.

(ii) Subtract step (i) from $14 \times A$.

(iii) Divide A by 140×60. Subtract the quotient from step (ii); the difference gives the *ahargaṇa*-derived Moon.

(iv) Subtract the product of *dhruvaka* and *cakra* ($C \times D$) from step (iii).

(v) Add *kṣepaka* K to step (iv) which gives the mean position of the Moon.

i.e., Mean longitude of the Moon =

$$\left[\left\{\left(A \times 14 - \frac{A \times 14}{17}\right) - \frac{A}{140 \times 60}\right\} - C \times D\right] + K$$

Example : $A = 3328$, $C = 41$, $D = 3^\circ 46' 11''$, $K = 11^R 19^\circ 6'$

Mean longitude of the Moon = $\left\{\left(A \times 14 - \frac{A \times 14}{17}\right) - \frac{A}{140 \times 60}\right\} - C \times D + K$

$$= \left\{ \left(3328 \times 14 - \frac{3328 \times 14}{17} \right) - \frac{3328}{140 \times 60} \right\} - 41 \times 3°46'11'' + 11^R 19°6'0''$$

$$= 44045°.439 = \mathbf{4^R 5°26'20''}$$

(removing completed revolutions).

Modern Example :

Given date : 11th August 1998

For the given date, $A = 2033$, $C = 43$

For the Moon : $D = 3°46'11''$, $K = 11^R 19°6'$

Mean longitude of the Moon $= \left[\left(A \times 14 - \frac{A \times 14}{17} \right) - \frac{A}{140 \times 60} \right] - C \times D + K$

$$= \left[\left(2033 \times 14 - \frac{2033 \times 14}{17} \right) - \frac{2033}{140 \times 60} \right] - 43 \times 3°46'11'' + 11^R 19°6'$$

$$= 26974°.525 = 11^R 4°31' = \mathbf{334°31'}$$

removing completed revolutions.

***Śloka* 11** : Mean positions of *Candrocca* (Moon's apogee) and Rāhu.

The method is explained as below :

(i) Divide *ahargaṇa* A by 9.

(ii) Again divide *ahargaṇa* A by 70 and it is in *kalās*.

Divide the result by 60 to get it in degrees.

(iii) Adding step (i) and step (ii), we get *ahargaṇa* derived *mandocca*.

(iv) Subtract the product of *cakra* and *dhruvaka* ($C \times D$) from step (iii)

(v) Add *kṣepaka* K to step (iv).

This gives the *Candrocca* (*mandocca* of the Moon).

i.e., Mean position of *Mandocca* = $\left[\left(\frac{A}{9}+\frac{A}{70\times 60}\right)^{\circ} - C\times D\right] + K$

Example : $A = 1521$, $C = 8$, $D = 9^R2^\circ45'$, $K = 5^R17^\circ33'$

Mean position of *Mandocca* = $\left[\left(\frac{A}{9}+\frac{A}{70\times 60}\right)^{\circ} - C\times D\right] + K$

$$= \left[\left(\frac{1521}{9}+\frac{1521}{70\times 60}\right)^{\circ} - 8\times 9^R2^\circ45'\right] + 5^R17^\circ33'$$

$$= 314^\circ54'43'' = \mathbf{10^R14^\circ54'43''}$$

Modern Example :

Given date : 11th August 1998

For the given date, $A = 2033$, $C = 43$

For *Mandocca*, $D = 9^R2^\circ45'$, $K = 5^R17^\circ33'$

$\therefore$ Mean position of *Mandocca* = $\left[\left(\frac{A}{9}+\frac{A}{70\times 60}\right)^{\circ} - C\times D\right] + K$

$$= \left(\frac{2033}{9}+\frac{2033}{70\times 60}\right)^{\circ} - 43\times 9^R2^\circ45' + 5^R17^\circ33'$$

$$= -11334^{\circ}.327 = 185^{\circ}.67294 \text{ (adding multiples of } 360^{\circ})$$

$$= 185^{\circ}40'22'' = 6^{R}\ 5^{\circ}\ 40'\ 22''.$$

Mean position of *Moon's Pāta* (Rāhu)

The following is the method to determine the mean position of *Pāta* (Rāhu).

(i) Divide *ahargaṇa* A by 19 (the result in degrees)

(ii) Divide *ahargaṇa* A by 45. Divide the result in *kalās* by 60 to get it in degrees

(iii) Add step (i) with step (ii)

(iv) Divide step (iii) by 30 to get the result in *Rāśis* and subtract the quotient from 12. This gives *cakra śuddha* Rāhu.

(v) Subtract the product of D and C from step (iv).

(vi) Add K to step (v). Then we will get

$$\text{Mean Rāhu} = \left\{12 - \frac{\left(\frac{A}{19} + \frac{A}{45 \times 60}\right)}{30}\right\}^{R} - C \times D + K$$

$$= \left\{360^{\circ} - \left(\frac{A}{19} + \frac{A}{45 \times 60}\right)\right\}^{\circ} - C \times D + K$$

Example : $A = 1521$, $C = 8$, $D = 7^{R}2^{\circ}50'$, $K = 27^{\circ}38'$

$$\text{Mean longitude of Rāhu} = \left\{360^{\circ} - \left(\frac{A}{19} + \frac{A}{45 \times 60}\right)\right\}^{\circ} - C \times D + K$$

$$= \left\{360^\circ - \left(\frac{1521}{19} + \frac{1521}{45 \times 60}\right)\right\}^\circ - 7^R 2^\circ 50' \times 8 + 27^\circ 38'$$

$= 44^\circ.350702 = 44^\circ 21' 2''.5 = 1^R\ 14^\circ 21' 2.5''$.

Modern example :

Given date : 11th August 1998

For the given date, $A = 2033$, $C = 43$

For Rāhu : $D = 7^R\ 2^\circ 50'$, $K = 27^\circ 38'$

$$\text{Mean longitude of Rāhu} = \left\{360^\circ - \left(\frac{A}{19} + \frac{A}{45 \times 60}\right)\right\}^\circ - C \times D + K$$

$$= \left\{360^\circ - \left(\frac{2033}{19} + \frac{2033}{45 \times 60}\right)\right\}^\circ - 43 \times 7^R 2^\circ 50' + 27^\circ 38'$$

$= -8871^\circ.953 = 128^\circ.04704$ (adding multiples of 360°)

$= 128^\circ 2' 49'' = 4^R\ 8^\circ\ 2'\ 49''$

***Śloka* 12** : (a) Mean position of Kuja

(i) Multiply *ahargaṇa* A by 10

(ii) Divide step (i) by 19 (the result is in degrees)

(iii) Divide step (i) by 73 (the result is in *kalās*)

(iv) Subtract step (iii) from step (ii), the result of which will be the *ahargaṇa* derived mean Kuja.

(v) Take the product of *cakra* and *dhruvaka* and subtract the product ($C \times D$) from step (iv).

(vi) Add *kṣepaka* (K) to step (v). Then

$$\text{Mean Kuja} = \left[\frac{10 \times A^\circ}{19} - \frac{10 \times A'}{73}\right] - C \times D + K$$

Example : Consider the date May 15, 1612 (G), Monday.

$A = 1521$, $C = 8$, $D = 1^R\,25°32'$, $K = 10^R\,7°8'$

$\therefore$ Mean longitude of Kuja

$$\left[\frac{10 \times 1521\ ^\circ}{19} - \frac{10 \times 152\ 1'}{73}\right] - 8 \times 1^R 25°32' + 10^R 7°8'$$

$= 800°.52632 - 208'.35616 - 8 \times 55°.53333 + 307°.13333$

$= 659°.92038 =$ **$9^R 29°55'13''$**

[removing the completed revolutions]

Modern Example : Given date : 11th August 1998

For the given date : $A = 2033$, $C = 43$

For Kuja : $D = 1^R 25°32'$, $K = 10^R 7°8'$

$$\therefore \text{Mean longitude of Kuja} = \left[\frac{10A^\circ}{19} - \frac{10A'}{73}\right] - C \times D + K$$

$$= \left[\frac{10 \times 2033\ ^\circ}{19} - \frac{10 \times 2033}{73}\right]' - 43 \times 1^R 25°32' + 10^R 7°8'$$

$= -\ 1015°.4416 = 64°.558448$

$=$ **$64°33'30''$** $= 2^R\ 4°\ 33'\ 30''$

(by adding multiples of 360°)

The method of finding *śīghrakendra* of Budha is as follows :

Śīghra normaly of Budha

(i) Multiply *ahargaṇa* by 3.

(ii) Divide $3A$ by 28.

(iii) Add step (i) and step (ii); the result will be in degrees.

(iv) Subtract $\frac{A}{38}$ *kalās* (minutes of arc) from step (iii)

the result of which will be the *ahargaṇa*-derived mean Budha *kendra*.

(v) Subtract the product of *cakra* and *dhruvaka* from step (iv)

(vi) Add *kṣepaka* (K) to (v).

i.e, *Śīghrakendra* of Budha $= \left[\left(\frac{3A}{28}+3A\right)^{\circ}-\left(\frac{A}{38}\right)'\right]-C\times D+K$

$$= \left[\left(\frac{3A}{28}+3A\right)-\left(\frac{A}{38\times 60}\right)'\right]^{\circ} - C\times D+K$$

Example : $A = 1521,\ C = 8,\ D = 4^{R}\ 3^{\circ}\ 27' = 123^{\circ}\ 27'$

and $K = 8^{R}\ 29^{\circ}\ 33' = 269^{\circ}\ 33'$

i.e, Mean *śīghrakendra* of Budha

$$= \left[\left(\frac{3A}{28}+3A\right)^{\circ}-\left(\frac{A}{38\times 60}\right)^{\circ}\right]-C\times D+K$$

$$= \left(\frac{3\times 1521}{28} + 3\times 1521\right)^{\circ} - \left(\frac{1521}{38\times 60}\right)^{\circ} - 8\times 123^{\circ}\ 27' + 269^{\circ}\ 33'$$

$$= 4007^{\circ}\cdot 2472 = 47^{\circ}\ \ 14'\ \ 49'' = \mathbf{1^{R}}\ \ 17^{\circ}\ \ 14'\ \ 49''$$

[removing the completed revolutions].

Modern example :

Given date : 11th August 1998

For the given date $A = 2033$, $C = 43$

We have for the Budha *kendra* : $D = 4^{R}\ 3^{\circ}\ 27'$, $K = 8^{R}\ 29^{\circ}\ 33'$

$$\text{Budha } \acute{S}\bar{\imath}ghra \text{ kendra} = \left[\left(\frac{3A}{28} + 3A\right)^{\circ} - \left(\frac{A}{38\times 60}\right)^{\circ}\right] - C\times D + K$$

$$= \left[\left(\frac{3\times 2033}{28} + 3\times 2033\right) - \left(\frac{2033}{38\times 60}\right)\right]^{\circ} - 43\times 4^{R}\ 3^{\circ}\ 27' + 8^{R}\ 29^{\circ}\ 33'$$

$$= 1277^{\circ}\cdot 12976 = 197^{\circ}\cdot 12976 = \mathbf{197^{\circ}\ 7'\ 47''}$$

(Removing the multiples of 360°)

Note : Usually the practice, in other *Siddhāntic* texts, is first to find the *Śīghrocca* of Budha and then to subtract the mean Budha (same as the mean Ravi) from it to get the *Śīghrakendra* of Budha. Similar is the practice in the case of Śukra's *Śīghrakendra*.

However, *Grahalāghavam* gives the method of determining the *śīghrakendras* of Budha and Śukra directly without finding the *śīghroccas*.

***Śloka* 13** : Mean positions of Guru and Śukra *kendra* are explained.

(i) Mean position of Guru :

The method is as explained below.

(i) Divide *ahargaṇa* A by 12. The result is in degrees.

(ii) Divide *ahargaṇa* A by 70. This will be in *kalās* (minutes).

(iii) Subtract step (ii) from step (i)

(iv) Subtract the product of *cakra* (C) and *dhṛuvaka* (D) from (iii).

(v) Add *kṣepaka* (K) to (iv).

i.e., Mean longitude of Guru = $\left[\left(\frac{A}{12}\right)^{\circ} - \left(\frac{A}{70}\right)'\right] - C \times D + K$

$$= \left[\left(\frac{A}{12}\right) - \left(\frac{A}{70 \times 60}\right)'\right]^{\circ} - C \times D + K$$

Example : $A = 1521$, $C = 8$, $D = 26^{\circ}\ 18'$

and $K = 7^{R}\ 2^{\circ}\ 16' = 212^{\circ}\ 16'$

$\therefore$ Mean longitude of Guru = $\left[\left(\frac{A}{12}\right)^{\circ} - \left(\frac{A}{70 \times 60}\right)^{\circ}\right] - C \times D + K$

$$= \left[\left(\frac{1521}{12}\right)^{\circ} - \left(\frac{1521}{70 \times 60}\right)^{\circ}\right] - 8 \times 26^{\circ}\ 18' + 212^{\circ}\ 16'$$

$= 128^\circ{\cdot}25452 = 128^\circ\ 15'\ 16'' = \mathbf{4^R\ 8^\circ\ 15'\ 16''}$

Modern example :

Given date : 11th August 1998

For the given date, $A = 2033$, $C = 43$

and for Guru $D = 0^R\ 26^\circ\ 18'$, $K = 7^R\ 2^\circ\ 16'$

$$\text{Now, Mean longitude of Guru} = \left[\left(\frac{A}{12}\right)^\circ - \left(\frac{A}{70 \times 60}\right)^\circ\right] - C \times D + K$$

$$= \left[\left(\frac{2033}{12}\right)^\circ - \left(\frac{2033}{70 \times 60}\right)^\circ\right] - 43 \times 26^\circ\ 18' + 7^R\ 2^\circ\ 16'$$

$$= -749^\circ{\cdot}70071 = 330^\circ{\cdot}29929 \quad (\text{adding } 1080^\circ)$$

$$= \mathbf{330^\circ\ 17'\ 57''} = 11^R\ 0^\circ\ 17'\ 57''$$

Mean *śīghrakendra* of Śukra :

The method to find out Śukra *kendra* is as follows :

(i) Multiply *ahargaṇa* A by 3.

(ii) Divide step (i) by 5.

(iii) Divide step (i) by 181.

(iv) Add step (ii) and step (iii). The result is in degrees.

(v) Subtract the product of *cakra* (C) and *dhruvaka* (D) from step (iv)

(vi) Add *kṣepaka* K to step (v)

i.e., Mean position of Śukra *Kendra* = $\left[\frac{3A}{5}+\frac{3A}{181}\right]^{\circ}-C\times D+K$

Example : A = 1521, C = 8, $D = 1^{R}\ 14^{\circ}\ 2' = 44^{\circ}\ 2'$,

$K = 7^{R}\ 20^{\circ}\ 9' = 230^{\circ}\ 9'$

$\therefore$ Mean position of Śukra *Kendra* = $\left[\frac{3A}{5}+\frac{3A}{181}\right]^{\circ}-C\times D+K$

$$=\left[\frac{3\times1521}{5}+\frac{3\times1521}{181}\right]-8\times 44^{\circ}\ 2'+230^{\circ}\ 6'$$

$$= 815^{\circ}\ 41'\ 35'' = 95^{\circ}\ 41'\ 36'' = 3^{R}\ 5^{\circ}\ 41'\ 35''$$

[removing the completed revolutions].

Modern example :

Given date : 11th August 1998

For the given date, A = 2033, C = 43

For Śukra *Kendra*, $D = 1^{R}\ 14^{\circ}\ 2'$, $K = 7^{R}\ 20^{\circ}\ 9'$

$\therefore$ Mean position of Śukra *kendra* = $\left(\frac{3A}{5}+\frac{3A}{181}\right)^{\circ}-C\times D+K$

$$=\left(\frac{3\times2033}{5}+\frac{3\times2033}{181}\right)^{\circ}-43\times1^{R}\ 14^{\circ}\ 2'+7^{R}\ 20^{\circ}\ 9'$$

$$= -409^{\circ}\ 47'\ 14'' = \mathbf{310^{\circ}\ 12'\ 46''}\ \text{(adding } 720^{\circ})$$

Śloka **14** : Mean longitude of Śani.

The method is as explianed below :

(i) Divide *ahargaṇa* A by 30. The result will be in degrees.

(ii) Divide *ahargaṇa* A by 156. The result will be in minutes of arc (*kalās*). Convert it into degrees by dividing by 60.

(iii) Add step (i) and step (ii).

(iv) Subtract the product of *cakra* (C) and *dhruvaka* (D) from step (iii).

(v) Add *kṣepaka* K to (iv).

i.e., Mean longitude of Śani $= \left[\left(\frac{A}{30}\right)^{\circ} + \left(\frac{A}{156}\right)'\right] - C \times D + K$

$$= \left[\left(\frac{A}{30}\right)^{\circ} + \left(\frac{A}{156 \times 60}\right)^{\circ}\right] - C \times D + K$$

Example : $A = 1521,\ C = 8,\ D = 7^{R}\ 15^{\circ}\ 42' = 225^{\circ}42'$

and *Kṣepaka* $K = 9^{R}\ 15^{\circ}\ 21' = 285^{\circ}\ 21'$

$\therefore$ Mean longitude of Śani $= \left[\left(\frac{A}{30}\right)^{\circ} + \left(\frac{A}{156 \times 60}\right)^{\circ}\right] - C \times D + K$

$$= \left[\left(\frac{1521}{30}\right)^{\circ} + \left(\frac{1521}{156 \times 60}\right)^{\circ}\right] - 8 \times 225^{\circ}42' + 285^{\circ}\ 21'$$

$= -1469^\circ{\cdot}3875 = 330^\circ{\cdot}6125$ (adding $5 \times 360^\circ$) $= \mathbf{11^R\ 0^\circ\ 36'\ 45''}$

Modern example :

Given date : 11th August 1998

For the given date, $A = 2033$, $C = 43$

For Śani, $D = 7^R\ 15^\circ\ 42'$ and $K = 9^R\ 15^\circ\ 21'$

$$\therefore \text{ Mean longitude of Śani} = \left[\left(\frac{A}{30}\right)^\circ + \left(\frac{A}{156 \times 60}\right)^\circ\right] - C \times D + K$$

$$= \left[\left(\frac{2033}{30}\right)^o + \left(\frac{2033}{156 \times 60}\right)^o\right] - 43 \times 7^7 15^o 42' + 9^R 15^o 21'$$

$= -9351^\circ.7661324 = 8.2338676$ (*adding* 26×360^o)

$= 8^\circ\ 14'\ 2''$

Śloka 15 : Mean daily motions of planets

Mean daily motions of planets (*madhyama gati*) are given in Table 1.6

Table 1.6 Mean daily motions of bodies

Bodies	Sun	Moon	*Candrocca*	Rāhu	Kuja	Budha *Kendra*	Guru	Śukra *Kendra*	Śani
Kalās (minutes)	59	790	6	3	31	186	5	37	2
Vikalās (seconds)	8	35	41	11	26	24	0	0	0

***Śloka* 16** : The values of the Sun and the Moon's *mandocca* (*Candrocca*) obtained from this text are equivalent to those according to the *Śūrya Siddhānta* (*SS*). By subtracting $9'$ from the Moon (as per this text) we get as per *SS*. The positions Kuja, Guru, Rāhu are in accordance with the *Āryapakṣa*. Budha *kendra* (Budha's *śīghra* anomaly) is in accordance with the *Brāhma pakṣa*. By adding $5°$ to Śani (obtained from this text), we get that according to the *Ārya Siddhānta*. The Śukra (*śīghra*) *kendra* (of this text) is half of the sum of those obtained from the *Ārya* and *Brāhma pakṣas* (i.e., the average of the latter two).

Derivations of expressions for the mean longitudes

The expressions for the mean longitudes of the Sun, the Moon, the Moon's apogee and node, given in Table 1.6 are now derived using the revolutions of these bodies and the numbers of civil days in a *Mahāyuga* of 432×10^4 years.

(i) Mean longitude of the Sun

The mean longitude of the Sun is given by

$$\lambda = \left(A - \frac{A}{70} - \frac{A}{150 \times 60} \right)^{\circ} - Cakra \times 1^{\circ}.81972 + 349^{\circ}.683$$

where A is the *ahargaṇa* according to *GL*.

Mean motion of the sun in a *Cakra*

1 *Cakra* = 4016 days

Number of civil days in a *Mahāyuga* = 1577917828 according to *Surya Siddhānta.*

Number of revolutions of the Sun in a *Mahāyuga* = 4320000

$\therefore$ Mean daily motion of the Sun = $\dfrac{4320000 \ rev.}{1577917828} = 59'8''\cdot 17$

Therefore, in a *Cakra*

Sun's motion $= 4016 \times 59'8''{\cdot}17$

$= 3958^{\circ}{\cdot}180756$

$= 10{\cdot}99494654$ revolutions

Subtracting 11^{rev}, we get *dhruvaka* $= -1^{\circ}{\cdot}8192444$

$= -1^{\circ}49'9''$ (approx)

The *ahargaṇa* derived mean motion of the Sun is given by $A \times 59'8''{\cdot}17$

Multiplying and dividing by 70, we get

$$\frac{70 \times A \times 59'8''{\cdot}17}{70} = \frac{4139'32'' \times A}{70}$$

$$= \frac{68^{\circ}59'32'' \times A}{70}$$

By adding and subtracting $28''$, the mean motion of the Sun

$$= \frac{A \times (68^{\circ}\ 59'\ 32'' + 28'' - 28'')}{70} = A \times \left(\frac{69^{\circ} - 28''}{70}\right)$$

$$= \frac{A \times 69^{\circ}}{70} - \frac{A \times 28''}{70} = \frac{A \times (69^{\circ} + 1^{\circ} - 1^{\circ})}{70} - \frac{A \times 28''}{70}$$

$$= \frac{A\times 70}{70} - \frac{A}{70} - \frac{A\times 28''}{70} = A - \frac{A}{70} - \frac{\frac{A}{70\times 60\times 60}}{28} \text{ degrees}$$

$$= A - \frac{A}{70} - \frac{A}{150\times 60} \text{ in degrees.}$$

(ii) Mean longitude of the Moon

The mean longitude of the Moon is given by

$$\lambda = A\times 14 - 14\times\frac{A}{17} - \frac{A}{140\times 60} - Cakra\ \times 3^\circ\cdot 76972 + 349\cdot 1 \text{ in deg.}$$

where A is the *ahargaṇa* according to *GL*.

Mean daily motion of the Moon $= 790'34''\cdot 9 = 13^\circ\ 10'\ 34''\cdot 9$

Mean motion of the Moon in a *Cakra* $= 4016\ \times 13^\circ\cdot 176361$

$$= 52916^\circ\cdot 26622 = 146^{rev.}\cdot 9896284$$

Subtracting 147 rev., we get

Dhruvaka $= -3^\circ\cdot 7337785$ (taken as $3^\circ\cdot 76972$ by *GL*).

$$= -\ 3^\circ\ 44'01\ .6$$

The mean longitude of the Moon $= A\times 13^\circ 10'34''\cdot 9$

Multiplying and dividing by 17 we get

$$\frac{A\times 17\times 13^\circ 10'34''\cdot 9}{17} = \frac{A\times 223^\circ 59'53''}{17}$$

$$= \frac{A\times(223^\circ 59'53''+7''-7'')}{17} = \frac{A\times(224^\circ-7'')}{17} = \frac{A\times 224^\circ}{17} - \frac{A\times 7''}{17}$$

$$= \frac{A\times(224^\circ+14^\circ-14^\circ)}{17} - \frac{A\times 7''}{17} = \frac{A\times 238^\circ}{17} - \frac{A\times 14^\circ}{17} - \frac{A\times 7''}{17}$$

$$= A\times 14^\circ - \frac{A\times 14^\circ}{17} - \frac{A\times 7''}{17\times 60\times 60} \text{ deg.}$$

$$= A\times 14^\circ - \frac{A\times 14^\circ}{17} - \frac{\dfrac{A}{1020\times 60}}{7}$$

$$= A\times 14^\circ - \frac{A\times 14^\circ}{17} - \frac{A}{145\cdot 71429\times 60}$$

Note : In the last term the text has made an approximation viz. $\dfrac{A^\circ}{140\times 60}$

(iii) Mean longitude of the Moon's apogee (*mandocca*)

The mean longitude of the Moon's apogee is given by

$$M = \frac{A}{9} + \frac{A}{70\times 60} - 272.75 \times Cakra + 167.55 \text{ in degrees}$$

where A is the *ahargaṇa* according to *GL.*

Number of civil days in a *Mahāyuga* = 1577917828

Number of revolutions of the Moon's apogee according to the *Sūrya Siddhānta* = 488203

Mean daily motion of the Moon's apogee $= \dfrac{488203 \ revns.}{1577917828} = 6'40''.98$

Mean motion of the Moon's apogee in a *cakra*

1 *cakra* = 4016 days

Mean daily motion of Moon's apogee = $6'40''.98$. Therefore, in 1 *cakra,*

the mean motion of the Moon's apogee $= 4016 \times 6'40''.98$

$$= 447^{\circ}.3154667 \qquad = 1.242542963 \ revns.$$

Subtracting 2 revolutions we get

Dhruvaka = $-\ 272^{\circ}.6845333$ (taken as $272^{\circ}.75$ by *GL*)

$$= -\ 272^{\circ}41'04''.32$$

The mean longitude of the Moon's apogee is given by $A \times 6'40''.98$

By multiplying and dividing by 9 we have

$$\frac{A \times 6'40''.98 \times 9}{9} = \frac{A \times 1^{\circ}0'8''}{9} = \frac{A^{\circ}}{9} + \frac{A \times 8'}{9 \times 60} = \frac{A^{\circ}}{9} + \frac{A'}{67.5}$$

In the last term, *GL* takes 70 instead of 67.5 in the denominator. This results in a maximum error of $2'$.

(iv) Mean longitude of *Rāhu*

The mean longitude of Rāhu is given by

$$\textbf{\textit{Rāhu}} = \left[360 - \left(\frac{A}{19} + \frac{A}{45 \times 60}\right) - (212.83 \times cakra) + 27.63\right] \text{degrees.}$$

where A is the *ahargaṇa* A according to *GL*

Mean daily motion of Rāhu $= 3'10''.8$

Mean motion of Rāhu in a *cakra* $= 4016 \times 3'10''.8$

$$= 212^\circ.848 = 212^\circ 50' \equiv \textit{Dhruvaka}$$

which is the same as given in *GL*

The mean motion of the Moon's node (Rāhu) is given by $A \times 3'10''.8$

for the *ahargaṇa* A.

Multiplying and dividing by 19 we have

$$\frac{A \times 3'10''.8 \times 19}{19} = \frac{A \times 1^\circ 0'25''}{19} = \frac{A^\circ}{19} + \frac{A \times 25''}{19} = \frac{A^\circ}{19} + \frac{A \times 25'}{19 \times 60}$$

$$= \frac{A^\circ}{19} + \frac{A^\circ}{45.6 \times 60}$$

GL has taken 45 instead of 45.6

(v) Mean longitude of *Kuja*

$$\text{Mean Kuja} = \frac{10}{19}A^\circ - \frac{10\,A}{73}\ \text{min} - (C \times D)\ \text{deg} + K\ \text{deg}$$

where A is the *ahargaṇa* according to *GL*.

Number of revolutions of Kuja in a *Mahāyuga* = 2296824

Number of civil days in a *Mahāyuga* = 1577917828

$$\therefore \text{ Mean daily motion of Kuja} = \frac{2296824 \text{ revns.}}{1577917828} = 31' \ 26''.4$$

Mean motion of Kuja in a *cakra* = $4016 \times 31'26''.4$

$$= 304^\circ 23' 2'' = -55^\circ 36' 57'' = \textit{Dhruvaka}$$

(by subtracting 360°)

Multiplying and dividing the *ahargaṇa* derived motion by 19 we have

$$\frac{A \times 31'26''.4 \times 19}{19} = \frac{A \times 597'}{19}$$

$$= \frac{A \times (597' \, 21'' + 2' \, 39'' - 2' \, 39'')}{19} = \frac{A \times 600'}{19} - \frac{A \times 2'39''}{19}$$

$$= \frac{A \times 600'}{19} - \frac{A \times 2'39'' \times 10}{19 \times 10} = \frac{A \times 10^\circ}{19} - \frac{\frac{A \times 10}{190}}{2'39''}$$

$$= \frac{A^\circ \times 10}{19} - \frac{A' \times 10}{71.698113} = \frac{A \times 10^\circ}{19} - \frac{A' \times 10}{72}$$

(vi) Mean *śīghra kendra* of Budha

Mean *śīghra kendra* of Budha is given by

$$3A^\circ + \frac{3A^\circ}{28} - \frac{A}{38} \text{ min} - (C \times D) \text{ deg.} + K \text{ deg.}$$

where A is the *ahargaṇa* according to *GL*.

In a Mahāyuga, we have

Number of revolutions of Budha's *śīghrocca* = 17937020

Number of civil days = 1577917828

$$\therefore \text{Mean daily motion of Budha's } \textit{śīghrocca} = \frac{17937020 \text{ revns.}}{1577917828} = 4^\circ 5' 32''.31$$

Śīghra anomaly = Budha's *śīghrocca* – Mean Budha

Daily motion of *śīghra* anomaly

= Daily motion of Budha *śīghrocca* – Daily motion of mean Ravi

$$= 4^\circ 5' 32''.31 - 59' 8''.17 = 3^\circ 6' 24''.14$$

Multiplying and dividing the *ahargaṇa* derived motion by 28 we have

$$\frac{A \times 3^\circ 6' 24''.14 \times 28}{28} = \frac{A \times 86^\circ 59' 15''.92}{28} = \frac{A^\circ \times 87^\circ}{28} - \frac{A \times 44''.08}{28}$$

$$A^\circ \times \left(3^\circ + \frac{3^{\circ''}}{28}\right) - \frac{A \times 44''.08}{28} = 3A^\circ + \frac{3A^\circ}{28} - \frac{\frac{A'}{28 \times 60}}{44''.08}$$

$$= 3A^\circ + \frac{3A^\circ}{28} - \frac{A'}{38.11}$$

The denominator of the last term has been taken as 38 in *GL*.

Note : In other texts *śīghra kendra* is obtained by calculating Budha's *śīghrocca* and mean longitude separately and then subtracting the latter from the former. But the *Graha Lāghavam* directly gives the formula to calculate the *śīghra kendra* for Budha and Śukra (the inferior planets).

(vii) Mean longitude of Guru

The mean longitude of Guru is given by

$$\frac{A^\circ}{12} - \frac{A'}{70} - (C \times D)\,\text{deg} + K\,\text{deg}$$

where A is the *ahargaṇa*, C is the *cakra* and D *dhruvaka* and K the *kṣepaka* respectively. According to *GL*, here $K = 212^\circ 16'$ and $D = 26^\circ\ 18'$. We have

Number of civil days in a *Mahāyuga* = 1577917828

Number of revolutions of Guru in a *Mahāyuga* = 364220

$$\text{Mean daily motion of Guru} = \frac{364220 \text{ rev.}}{1577917828} = 4'59''.1468$$

$$\text{Mean motion of Guru in a } cakra = 4016 \times 4'59''$$

$$= \frac{4016 \times 364220}{1577917828} = 333^\circ 42' \Rightarrow 333^\circ 42' - 360^\circ$$

$= -\ 26^\circ 18'$ so that *Dhruvaka* $D = 26^\circ 18'$

Mean motion of Guru for *ahargaṇa* $A = 4'\ 59''.1468$

Multiplying and dividing by 12 we get

$$\frac{A \times 4'\,59''.1468 \times 12}{12} = \frac{A \times 59'\,49''.762}{12} = \left(\frac{60' - 10''.238}{12}\right) A$$

$$= \frac{A^\circ}{12} - \frac{10''.238 \times A}{12} = \frac{A^\circ}{12} - \frac{10.238 \times A}{12 \times 60} = \frac{A^\circ}{12} - \frac{A'}{70.32}$$

Note : The *GL* has taken 70 in the denominator of last term.

(viii) Mean *śīghra kendra* of Śukra

The mean longitude of Śukra's *śīghrakendra* is given by

$$\frac{3A^\circ}{5}+\frac{3A^\circ}{181}-(C\times D)\text{ deg.}+K\text{ deg.}$$

where A is the *ahargaṇa*, C the *cakra* and D *dhruvaka* and K the *kṣepaka* according to *GL*.

We have in Mahayuga

Number of revolutions of Śukra's *śīghrocca* = 7022388

Number of civil days in a *Mahāyuga* = 1577917828

$\therefore$ Mean daily motion of Śukra's *śīghrocca* = $\dfrac{7022388}{1577917828}\times 360^\circ$

$= 1^\circ\ 36'\ 7''.74$

Śīghra anomaly = Śukra's *śīghrocca* – Mean Śukra.

Here the mean Śukra is the same as the mean Sun.

$\therefore$ Daily motion of the *śighra* anomaly

= Daily motion of Śukra's *śīghrocca* – Daily motion of mean Sun

$= 1^\circ\ 36'\ 7''.74\ -\ 59'\ 8''.17\ = 36'\ 59''.57$

The mean motion for *ahargaṇa* $A = A\times 36'\ 59''.57$

By multiplying and dividing the *ahargaṇa* by 5 we get

$$\frac{A\times 36'\,59''.57\times 5}{5}=\frac{A\times 184'57''2'''}{5}=\frac{3^\circ 4'57''2'''\times A}{5}$$

$$\frac{A \times 3^\circ}{5} + \frac{A \times 4'57''2'''}{5} = \frac{A \times 3^\circ}{5} + \frac{A(3' + 1'57''2''')}{5}$$

$$= \frac{3A^\circ}{5} + \frac{A\,(3' + 1'57''2''')^\circ}{5 \times 60} = \frac{3A^\circ}{5} + \frac{A \times 3^\circ}{\dfrac{5 \times 60 \times 3}{4|57|2}} = \frac{3A^\circ}{5} + \frac{3A^\circ}{181}$$

as taken in the *Grahalāghavam*.

(viii) Mean longitude of Śani

$$\text{Mean Śani} = \frac{A^\circ}{30} + \frac{A^\circ}{156} - (C \times D)\ \text{deg.} + K\ \text{deg.}$$

where A is the *Ahargaṇa*, C the *cakra* and D *dhruvaka* and K the *kṣepaka* according to *GL*.

Number of civil days in a *Mahāyuga* = 1577917828

Number of revolutions of Śani in a *Mahāyuga* = 146564

$$\text{Mean daily motion of Śani} = \frac{146564 \times 360^\circ}{1577917828} = 2'0''.38$$

The mean motion for *ahargaṇa* A = $A \times 2'\,0''.38$

Multiplying and dividing the *ahargaṇa* derived motion by 30 we get

$$\frac{A \times 2'0''.38 \times 30}{30} = \frac{60'11.6'' \times A}{30} = \frac{A^\circ \times 1}{30} + \frac{11'.6 \times A}{30 \times 60}$$

$$= \frac{A^\circ}{30} + \frac{A'}{\dfrac{30 \times 60}{11.6}} = \frac{A^\circ}{30} + \frac{A'}{155.172}$$

The second term is considered as $\dfrac{A'}{156}$ by *GL*

i.e., Mean Śani $= \dfrac{A^\circ}{30} + \dfrac{A'}{156}$

CHAPTER 2

Ravi Candra Sphuṭādhikāra

(True Positions of the Sun and the Moon)

2.1. Introduction

In obtaining the mean positions of the Sun and the Moon, it was assumed that these bodies move in circular orbits round the earth with uniform angular velocities. However, by observations it was found that the motions are non-uniform.

The procedure for calculating the major corrections to the mean positions in order to obtain the true positions, is related to the epicyclic theory which is explained in the following section.

2.2. Epicyclic theory and *Mandaphala*

The theory is that while the mean Sun or the Moon moves along a big circular orbit (dotted in Fig.2.1), the actual (or true) Sun or Moon

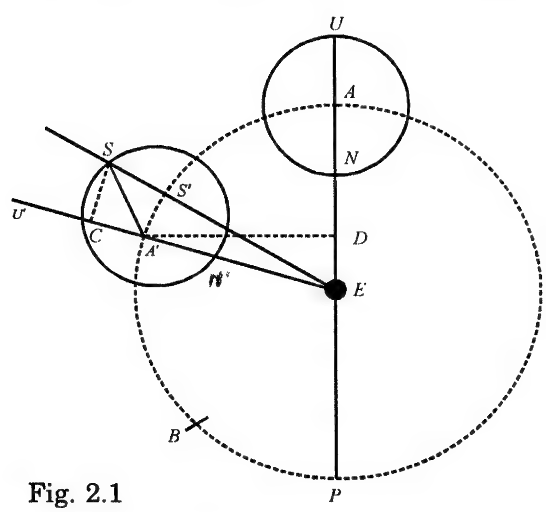

Fig. 2.1
Epicyclic Theory

moves along another smaller circle, called *epicycle*, whose centre is on the bigger circle.

The bigger circle *ABP* with the earth *E* as its centre is called the *kakṣavṛtta*. Let *A* be the position of the mean Sun when the true Sun is farthest from the earth. The line *AEP* is called the apse line (or ***nīcoccarekhā***) and *AE* is the *trijyā* (radius) of this orbit. The epicycle, with *A* as centre and a prescribed radius (smaller than *AE*) is called the *nīcoccavṛtta*. Let the apse line *PEA* cut the epicycle at *U* and *N*. The two points *U* and *N* are respectively called the *mandocca* (apogee)and the *mandanīca* of the Sun. Note that as the Sun moves (as seen from the earth) along the epicycle, he is farthest from the earth when he is at *U* and nearest when at *N*.

The epicyclic theory assumes that as the centre of the epicycle (i.e. mean Sun) moves along the circle *ABP* in the direction of the signs (from west to east) with the velocity of the mean Sun, the true Sun himself moves along the epicycle with the same velocity but in the opposite direction (from east to west). Further, the time taken by the Sun to complete one revolution along the epicycle is the same as that taken by the mean Sun (i.e., centre of the epicycle), to complete a revolution along the orbit.

Now, in Fig 2.1, suppose the mean Sun moves from A to A'. Let $A'E$ be joined cutting the epicycle at U' and N' which are the current positions of the apogee (*mandocca*) and the ***mandanīca.*** While the mean Sun is at A', suppose the true Sun is at *S* on the epicycle so that $U'\hat{A}'S = U'\hat{E}A$. Join *ES* cutting the orbit (i.e., circle *ABP*) at S'. Then A' is the *madhya* (mean Sun) and S' is ***spaṣṭa*** **(or *sphuṭa*)** Ravi. The difference between the two positions viz, $A'\hat{E}S'$ (or arc $A'S'$) is called the equation of centre (*mandaphala*).

Now, in order to obtain the true position of the Sun, it is necesary to get an expression for the equation of centre which will have to be applied to the mean position.

In Fig. 2.1, SC and $A'D$ are drawn perpendicular to $U'N'E$ and UNE respectively. The arc AA' (or $A\hat{E}A'$), the angle between the mean Sun and the apogee is called the mean anomaly (*mandakendra*) of the Sun.

We have, in the right-angled triangle $A'DE$,

$$\sin A\hat{E}A' = \sin D\hat{E}A' = A'D / A'E$$

so that

$$A'D = R \sin AA' = R \sin m$$

(where $R = A'E$ and m = arc AA') is called *mandakendrajyā*. From the similar right-angled triangles SCA' and $A'DE$, we have

$$SC / SA' = A'D / A'E$$

so that

$$SC = A'D \times SA' / A'E$$

Since SA' and $A'E$ are respectively the radii of the epicycle and the orbit, these are proportional to the circumferences of the two circles; that is,

$SA' / A'E =$ circumference of the epicycle / circumference of the orbit

$\therefore$ SC = (circumference of epicycle / circumference of orbit) $\times A'D$

Taking the circumference of the orbit as $360°$, we have

SC = (circumference of the epicycle) $\times$ (***mandakendrajyā***) / $360°$.

Now, taking SC approximately the same as $A'S'$, we have

Equation of centre (***mandaphala***)

= (circumference of the epicycle) $\times$ (***mandakendrajyā***) / $360°$

$= (r/R)(R \sin m)$

where R sin (m) the "Indian sine" of the anomaly m of the Sun. The maximum value of the equation of centre is r, the radius of the epicyle. By observation this can be obtained as the maximum deviation of the Sun's position from the calculated mean position. Note that when the Sun is at his apogee or perigee, the mean and true positions coincide since sin (m) is 0 when $m = 0°$ or $180°$.

The maximum equation of centre for the sun was observed by Bhāskara II to be $2° 11' 30''$ (*i.e.* $131'.5$) which is the value of r. Therefore,

circumference of the epicycle of the Sun

$$= (131.5 / 3438) \times 360° = 13°.66$$

This value is given by Bhāskara II.

Note : The same epicycle theory is applied to the Moon also. In the case of the Moon, Bhāskara II has given the maximum equation of centre as $302'$. Most texts have taken the epicycles as of varying radii and not fixed.

Table 2.1 : Peripheries of Epicycles of Apsis

Bodies	*Āryabhaṭīyam*	*Khaṇḍa Khādyaka*	*Saura siddhānta* (Varāhamihira)	*Sūrya Siddhānta*
Ravi	13°30′	14°	14°	13°40′ *to* 14°
Candra	31°30′	31°	31°	31°40′ *to* 32°
Kuja	63.0° *to* 81.0°	70°	70°	72° *to* 75°
Budha	22.5° *to* 31.5°	28°	28°	28° *to* 30°
Guru	31.5° *to* 36.5°	32°	32°	32° *to* 33°
Śukra	9.0° *to* 18.0°	14°	14°	11° *to* 12°
Śani	40°.5 *to* 58.5°	60°	60°	48° *to* 49°

From Table 2.1 we notice that the *Khaṇḍa Khādyaka* of Brahmagupta and the *Saurasiddhānta* (as given by *Varāhamihira*) take the epicycles as of constant periphery (and hence radius). The *Āryabhaṭīyam* except for the Sun and the Moon and the later *Sūrya Siddhānta* take them as varying between two limits.

2.3 Bhujāntara correction

The true midnight of a place differs from the mean midnight by an amount of time called "equation of time". The equation of time is caused by

(i) the eccentricity of the earth's orbit; and

(ii) the obiliquity of the ecliptic with the celestial equator.

The correction to the longitude of a planet due to the part of the equation of time caused by the eccentricity of the earth's orbit is called *bhujāntara*. The other correction caused by the obliquity of the ecliptic is called *udayāntara*.

While all the *siddhāntic* texts have considered the *bhujāntara* correction the other correction-*udayāntara*-was first introduced by *Śrīpati* (about 1025 AD) and later followed by Bhāskara-II and others.

We shall discuss the *bhujāntara* correction which is mentioned in the *Sūrya Siddhānta.* The effect of eccentricity of the earth's orbit in the equation of the centre (*mandaphala*) of the sun is converted into *time* at the rate of $15°$ per hour or $6°$ per *ghatikā*. This rate of conversion is due to the fact that the earth rotates about its axis at the rate of $360°$ in 24 hours (or 60 *ghaṭikās.*). The resulting amount in time unit is the *equation of time* caused by the eccentricity of the earth's orbit. Thus, the equation of time (due to the eccentricity)

= [(Equation of cente of the Sun) / 15] hours

= [(Equation of centre of the Sun) / 6] ***ghaṭikās***

Now, to get the *bhujāntara* correction for the Sun or the Moon or any other planet, the equation of time obtained above must be multiplied by the motion of the planet per hour or per ***ghaṭikā*** as the case may be. That is,

Bhujāntara correction for a planet

= [(Equation of time in hours] × (Daily motion)/24]

= [(Equation of centre of the Sun)/15] × [Daily motion)/24]

= [(Equation of centre of the Sun)] × (Daily motion)/360

where the factors in the numerator are in degrees and the daily motion is that of the planet. If the time unit used is *ghaṭikā*, then

Bhujāntara correction

= (Eqn. of time in *ghaṭikā*) × (Daily motion)/60]

= [(Eqn. of centre of the Sun in degrees)/6] × (Daily motion of the planet)/60]

= [Eqn. of centre of the Sun in degrees] × [Daily motion of the planet/360]

where the daily motion of the planet is in degrees and hence the *Bhujāntara* correction is also in degrees.

However, if the daily motion of the planet is in minutes of arc, then

Bhujāntara correction in degrees

= (Eqn. of centre of the Sun in degrees) $\times$ (Daily motion of the planet)/21600

Further, the *bhujāntara* correction is additive or subtractive according as the equation of centre of the Sun is so.

For example, in the case of Moon, its mean daily motion is $13^\circ.176352$ or $790'.58112$.

Therefore, we have (mean) *bhujāntara* correction

= (Eqn. of centre of the Sun) $\times\, 790'.58112/21600'$

= Eqn. of centre of the Sun/27.321674

Note : Brahamagupta takes the denominator approximately as 27 in his *Khaṇḍakhādyaka.*

It is important to note that to obtain the actual (and not the mean) *bhujāntara* correction of a planet, we have to use the true daily motion of the planet for the given day.

Example : Find the *bhujāntara* correction for the longitudes of the Sun and the Moon given that on a certain day

True daily motion of the Sun	:	$59'.65$
True daily motion of the Moon	:	$855'.23$
Equation of centre of the Sun	:	$+2^\circ 7' 32'' = 127'.53$

Therefore, we have

(i) True *bhujāntara* correction of the Sun

= (Eqn. of centre of the Sun) $\times$ (Daily motion of the Sun)/21600

$= 127'.53 \times 59'.65 / 21600' = 0'.3521835 = 0'21''$

Since the equation of centre of the Sun is additive, the *bhujāntara* correction is also additive.

(ii) True *bhujāntara* correction of the Moon

= (Eqn. of centre of the Sun) × (Daily motion of the Moon)/21600

$= 127'.53 \times 855'.23 / 21600' = 5'.0494205 = 5'3''$

Here also, the correction is additive since the Sun's equation of centre is so.

2.4 Further corrections for the Moon

We have applied so far an important correction namely, the equation of centre (*mandaphala*), to the mean position of the Moon. Besides this correction, the other two corrections applied viz, *deśāntara* and *bhujāntara* are mainly to get the true position of the moon at the true local midnight at the place of observation.

However, to get the true position of the Moon at least two more important corrections will have to be applied, of course, ignoring other minor corrections due to planetary perturbations. These are :

(i) **Evection** $= (15/4)' \, m e \sin(2\xi - \phi) = 76' \, 26'' \sin(2\xi - \phi)$

where m is the ratio of mean daily motions of the Sun and the Moon, e is the eccentricity of the Moon's orbit, $\xi = (M - S)$, the elongation of the Moon from the Sun and $\phi = M - P$, the mean anomaly of the moon (P being the Moon's perigee).

(ii) **Variation** $= 39' \, 30'' \sin(2\xi)$

In the above formulae, S and M are respectively the mean longitudes of the Sun and the Moon. The *Sūrya Siddhānta*, being an earlier text, does not mention these corrections. However, Mañjula (932 A.D.),

text, does not mention these corrections. However, Mañjula (932 A.D.), Bhākara-II (1150 AD) and later Indian astronomers have recognized the *evection* correction in addition to the equation of centre. Besides these, the famous Orissa astronomer **Sāmanta Candraśekhara Simha** discovered independently a fourth correction called *annual equation*. According to Candraśekhara,

(iii) **Annual equation** = $(11'27''.6)$ sin(Sun's anomaly from apogee)

In fact, Candraśekhara's coefficient viz., $11'27''.6$ is very close to the known modern value. Tycho Brahe took the coefficient wrongly as $4'30''$.

Śloka 1 : In this *śloka* the *mandakendra* (anomaly) of a planet and the *bhuja* of *mandakendra* are given as follows :

Mandakendra (*MK*) = *Mandocca* of the planet – Mean planet

(i) If the *mandakendra* of the planet is less than 3 *rāśis* (i.e., $0° < MK < 90°$), then *MK* itself is the *bhuja* i.e., *Bhuja* = *MK*.

(ii) If the *mandakendra* is greater than 3 *rāśis* and less than 6 *rāśis* (i.e., $90° < MK < 180°$) then

Bhuja = 6 *rāśis* – *MK* = $180° - MK$

(iii) If *mandakendra* is greater than 6 *rāśis* and less than 9 *rāśis* (i.e., if $180° < MK < 270°$) then *Bhuja* = *MK* – 6 *rāśis* = $MK - 180°$

(iv) If *mandakendra* is greater than 9 *rāśis* and less than 12 *rāśis* (i.e., $270° < MK < 360°$) then

Bhuja = 12 *rāśis* – *MK* = $360° - MK$

i.e., *koṭi* = 3 *rāśis* – *bhuja* = 90° – *bhuja*

12 *rāśis* (or 360°) have been divided into four *pādas* (quadrants) each containing 3 *rāśis* (90°). The I and III quadrants are *viṣamapādas* (odd quadrants) and II and IV are called *samapāda* (even quadrants).

Mandocca of the Sun = $78^{\circ} = 2^{R}\,18^{\circ}$ (taken as fixed).

***Śloka* 2** : The method of finding the *mandaphala* of the Sun is explained as follows:

(i) Find the *mandakendra* (*MK*) of the Sun.

(ii) Find the *bhuja* of *MK* (hereafter denoted by *BMK*).

(iii) Subtract $\frac{bhuja}{9}$ from 20 i.e., obtain (20 – *BMK*/9)

(iv) Multiply the results of step (iii) and $\frac{BMK}{9}$

(v) Divide the result of (iv) by 9.

(vi) Subtract the result of step (v) from 57.

(vii) Express the results of step (vi) and step (iv) as *vīkalās* (seconds of arc) and divide the result of step (iv) by that of step (vi)

The result is the *mandaphala* of the Sun.

i.e., ***Mandaphala* of the Sun** = $$\frac{\left(20-\frac{BMK}{9}\right)\frac{BMK}{9}}{57-\left\{\frac{\left(20-\frac{BMK}{9}\right)\frac{BMK}{9}}{9}\right\}}$$

Note :

(i) If the *mandakendra* is within 6 *rāśis* from *Meṣa* (i.e., $0^\circ < MK < 180^\circ$) then the *mandaphala* is additive.

(ii) If the *mandakendra* is within 6 *rāśis* from *Tulā* ($180^\circ < MK < 360^\circ$) then the *mandaphala* is subtractive.

Rationale for the *mandaphala* of the Sun

Śrīpati Bhaṭṭa's expression for the *jyā* of the *mandakendra* is as follows :

दोः कोटिभागरहिताऽभिहताः खनागचन्द्रास्तदीयचरणोनशरार्कदिग्भिः ।
ते व्यासखण्डगुणिता विहृताः फलन्तु ज्याभिर्विनाऽपि भवतो भुजकोटिजीवे ॥

doḥ koṭibhāgarahitā bhihatāḥ khanāgacandrāstadīya-caraṇonaśarārkadigbhiḥ /
te vyāsakhaṇḍaguṇitā vihṛtāḥ phalntu jyābhirvinā'pi bhavato bhujakoṭijīve //

i.e., *Mandakendra jyā* = $\dfrac{(180-MK)\,MK \times 120}{10125 - \dfrac{(180-MK)}{4}\,MK}$

where *MK* stands for the *bhuja* of the *mandakendra*

i.e., *Jyā* (*MK*) = $\dfrac{(180-MK)\,MK \times 480}{40500-(180-MK)\,MK}$

$$= \frac{\left(\dfrac{180-MK}{9}\right)\dfrac{MK}{9}\times 480}{\dfrac{40500}{9\times 9}-\left(\dfrac{180-MK}{9}\right)\dfrac{MK}{9}} \text{ (dividing by } 9 \times 9)$$

$$= \frac{\left(20 - \frac{MK}{9}\right)\frac{MK}{9} \times 480}{500 - \left(20 - \frac{MK}{9}\right)\frac{MK}{9}} \qquad \text{....... (i)}$$

The above derivation is based on the significant and unique formula of Bhāskara I (c.629 AD) - see Appendix-3

Now, according to the *Grahalāghavam*,

the *parama mandaphala* (i.e., maximum *mandaphala*) of the Sun

$$= \frac{125^{\circ}}{57} \approx 2^{\circ}11'34''.$$

$\therefore$ *Mandaphala* of the Sun $= \dfrac{125}{57} \times \dfrac{\textit{mandakendrajyā}}{120}$

$$= \frac{125}{57 \times 120} \times \left[\frac{\left(20 - \frac{MK}{9}\right)\frac{MK}{9} \times 480}{500 - \left(20 - \frac{MK}{9}\right)\frac{MK}{9}}\right] \text{ using (i)}$$

$$= \frac{\frac{125}{57}\left[\left(20 - \frac{MK}{9}\right)\frac{MK}{9} \times 4\right]}{500 - \left(20 - \frac{MK}{9}\right)\frac{MK}{9}}$$

$$= \frac{\left(\frac{500}{57}\right)\left[\left(20 - \frac{MK}{9}\right)\frac{MK}{9}\right]}{500 - \left(20 - \frac{MK}{9}\right)\frac{MK}{9}}$$

$$= \frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{\frac{500}{\left(\frac{500}{57}\right)}-\frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{\left(\frac{500}{57}\right)}}$$

$$= \frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{57-\frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{8.7719298}}$$

i.e., ***Mandaphala* of the Sun** $\approx \frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{57-\left\{\frac{\left(20-\frac{MK}{9}\right)\frac{MK}{9}}{9}\right\}}$

Note : The exact formula for the *mandaphala* of the Sun is $\frac{a}{R}$ sin m where $R = 360^\circ$, a the periphery of the *manda* epicycle (degrees) and m is the Sun's anomaly (from the apogee, *mandocca*).

When $m = 90^\circ$, sin m = 1 $\therefore$ *parama mandaphala* = $\frac{a}{R}$ *radian*

According to the *Grahalāghavam,*

$$\frac{a}{R} \times \frac{180}{\pi} = \frac{125}{57} \text{ degrees}$$

$$\Rightarrow \frac{a}{2} \times \frac{1}{\pi} = \frac{125}{57} \text{ (taking } R = 360^\circ\text{)}$$

$$\Rightarrow a = \frac{2\pi \times 125}{57} \text{ degrees}$$

$$\Rightarrow a = 13^\circ.778915$$

According to the book, *Ancient Indian Astronomy* by S. Balachandra Rao, the value of a for the Sun is between $11^\circ.80781$ and $12^\circ.31284$, based on the eccentricity of the earth's orbit.

Example : *Mandocca* of the Sun = $2^R\, 18^\circ$ (fixed)

Mean Sun = $1^R\, 4^\circ 13' 42''$

Mandakendra of the Sun (*MK*) = *Mandocca* – Mean Sun

$$= 2^R\, 18^\circ - 1^R\, 4^\circ 13' 42''$$

$$= 43^\circ 46' 18''$$

Since $0 < MK = (43^\circ 46' 18'') < 90^\circ$,

Bhuja of *MK* = $43^\circ 46' 18''$ denoted by *BMK*.

$$\therefore \; \textit{Mandaphala} \text{ of the Sun} = \frac{\left(20-\frac{BMK}{9}\right)\frac{BMK}{9}}{57-\left\{\frac{\left(20-\frac{BMK}{9}\right)\frac{BMK}{9}}{9}\right\}}$$

$$= \frac{73.616558}{48.820382} = 1^\circ.5079062 = \mathbf{1^\circ 30' 28''}$$

Mandaphala is additive because $0^\circ < MK \; (= 43^\circ 46' 18'') < 180^\circ$.

Note : According to the formula, using the sine function, we have

Mandaphala of the Sun $= \frac{a}{R} \sin m$ (where $a = 14^\circ$, $R = 360^\circ$, $m = 43^\circ 46' 18''$)

$$= \frac{14}{360} \sin(43^\circ 46' 18'') = 0.0269027 \text{ radian} = \mathbf{1^\circ 32' 29''}$$

We note that the *mandaphala* of the Sun, without the sine-function, is very close to that obtained using the trigonometric function. The error is just $2'$.

Now,

Mandaphala corrected Sun = Mean Sun + *Mandaphala*

$$= 1^R\, 4^\circ 13' 42'' + 1^\circ 30' 28''$$

$$= 1^R\, 5^\circ 44' 10''$$

After the *manda* correction, the *Grahalāghavam* adopts the *cara* correction explained in *śloka* 6 of this chapter.

Śloka **3** : In this *śloka* the method of finding the *mandaphala* of the Moon is given as follows :

(i) Find the *Mandakendra* (*MK*) of the Moon.

(ii) Subtract $\frac{MK}{6}$ from 30.

(iii) Multiply the result of step (ii) by $\frac{MK}{6}$.

(iv) Divide the result of step (iii) by 20 and subtract the quotient from 56.

(v) Divide the result of step (iii) by that of step (iv).

The result gives the *mandaphala* of the Moon.

i.e., *Mandaphala* of the Moon = $$\frac{\left(30-\frac{MK}{6}\right)\frac{MK}{6}}{56-\left\{\frac{\left(30-\frac{MK}{6}\right)\frac{MK}{6}}{20}\right\}}$$

Here, *MK* is actually the *bhuja* of the *mandakendra*.

Note : In the case of the Moon, the *Grahalāghavam gives* three corrections in the order, *cara*, *bhujāntara* and *deśāntara*. After obtaining the Moon with these three corrections, finally the *manda* correction (i.e., the equation of centre) is applied.

Rationale for the *mandaphala* of the Moon

We have *mandakendra jyā* $= \dfrac{(180 - MK)\,MK \times 480}{40500 - (180 - MK)\,MK}$

according to Śrīpati Bhaṭṭa.

Dividing the numberator and the denominator by 6×6,

$$Jy\bar{a}\ (MK) = \frac{\left(\dfrac{180 - MK}{6}\right) MK \times \dfrac{480}{6}}{\dfrac{40500}{6 \times 6} - \left(\dfrac{180 - MK}{6}\right)\dfrac{MK}{6}} \qquad \ldots\ldots\ldots. \text{ (i)}$$

According to the *Grahalāghavam* the maximum *mandaphalam,*

Parama mandaphala of the Moon = $5°$

$\therefore$ *Mandaphala* of the Moon $= \dfrac{5 \times mandakendrajy\bar{a}}{120}$

$$= \frac{5 \times \left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6} \times 480}{120 \times \left[1125 - \left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6}\right]} \qquad \text{using (i)}$$

$$= \frac{\dfrac{2400}{120}\left[\left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6}\right]}{1125 - \left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6}}$$

$$= \frac{20\left[\left(30 - \frac{MK}{6}\right)\frac{MK}{6}\right]}{1125 - \left(30 - \frac{MK}{6}\right)\frac{MK}{6}}$$

$$= \frac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{\frac{1125}{20} - \frac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{20}}$$

$$= \frac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{56.25 - \left\{\frac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{20}\right\}}$$

i.e., ***Mandaphala* of the Moon** $\approx \dfrac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{56 - \frac{\left(30 - \frac{MK}{6}\right)\frac{MK}{6}}{20}}$

This is the expression given by the *Grahalāghavam*.

Note : The usual formula for the *mandaphala* of the Moon is $\frac{a}{R}\sin m$.

When $m = 90°$, $\sin m = 1$ so that max. *mandaphala* = $\frac{a}{R}$ *radian*

Now, according to the *Grahalāghavam*. the maximum *mandaphala*.

Parama mandaphala of the Moon = $5°$

i.e, $\frac{a}{R}\times\frac{180}{\pi}=5 \quad \Rightarrow \quad \frac{a}{360}\times\frac{180}{\pi}=5$

$\Rightarrow \quad a=2\pi\times5 \quad \Rightarrow \quad a = \mathbf{31°.415927}$

According to the book *Ancient Indian Astronomy* by S. Balachandra Rao the value of *a* for the Moon lies between $36°.8085$ and $42°.22932$ based on the eccentricity of the Moon's orbit.

Śloka **4** : The method of finding true daily motions of the Sun and the Moon is given in this *śloka* as explained below.

I. True daily motion of the Sun :

We first find the '*gatiphalam*' as follows :

(i) Find the *bhuja* of the *mandakendra* (*MK*) of the Sun in degrees.

(ii) Find *koṭi* of *MK*.

(iii) Divide *koṭi* by 20.

(iv) Subtract the result of step (iii) from 11.

(v) Multiply the results of step (iii) and step (iv).

(vi) Divide the result of step (v) by 13. This gives the '*gatiphalam*' of the Sun in *kalās* (minutes of arc)

i.e., *Gatiphalam* of the Sun = $\dfrac{\left[\left(11-\dfrac{koṭi}{20}\right)\left(\dfrac{koti}{20}\right)\right]}{13}$

If *the mandakendra* of the Sun is within 6 *rāśis* from *Karka* (i.e., if $90° < MK < 270°$) then add *'gatiphalam'* to the mean daily motion of the Sun to get true daily motion.

If *mandakendra of* the Sun is within 6 *rāśis* from *Makara* (i.e., if *MK* is in IV or I quadrant), subtract *'gatiphalam'* from the mean daily motion to get true daily motion of the Sun.

Example :

Mandakendra (*MK*) of the Sun = $43°46'18''$ $\therefore$ *bhuja* = $43°\ 46'\ 18''$

Koṭi of *MK* $= 90° - bhuja$

$= 90° - 43°46'18'' = 46°13'42''$

$\therefore$ *Gatiphalam* of the Sun $= \dfrac{\left(11-\dfrac{koti}{20}\right)\dfrac{koṭi}{20}}{13}$

$= \dfrac{\left(11-\dfrac{46°13'42''}{20}\right)\dfrac{46°13'42''}{20}}{13}$

$= 1'.5448413 = 1'\ 32''\ 41'''.43$

Since *MK* of Ravi is in the first quadrant (i.e., within 6 *rāśis* from *Makara*)

we have to subtract *'gatiphalam'* from the mean daily motion of the Sun

$\therefore$ True daily motion of the Sun = Mean motion - *'gatiphalam'*

$$= 59' 8'' - 1' 32'' 41'''.43 = 57' 35'' 18'''.57$$

Remark : The modern formula for correction to get the true motion of the Sun is given by

$$\Delta n = \frac{-b}{R} \cos M \left(\frac{\Delta M}{\Delta t}\right)$$

where $b = 14$, $R = 360$ and the mean daily motion of the Sun,

$\dfrac{\Delta M}{\Delta t} = 59'08''$ (based on the classical sine formula).

$$\therefore \Delta n = \frac{-14}{360}\left[\cos(43^\circ 46' 18'')\right](59'08'')$$

$$= -1'39''54'''$$

Remark : The *gatiphalam* of the Sun, obtained without the use of trigonometric function differs from that using cos M only by $7''$ of arc.

II. True daily motion of the Moon

We first find *'gatiphalam'* as follows :

(i) Find the *mandakendra MK* of the Moon and its *bhuja.*

(ii) Find *koṭi* of the *mandakendra* (*MK*); *koṭi* = 90° – *bhuja.*

(iii) Divide *koṭi* by 20.

(iv) Subtract the result of step (iii) from 11.

(v) Multiply the results of steps (iv) and (iii).

(vi) Multiply the result of step (v) by 2.

(vii) Divide the result of step (vi) by 6.

(viii) Add the results of steps (vi) and (vii).

i.e., *Gatiphalam* of the Moon $= \left[\left(11 - \frac{koṭi}{20}\right)\frac{koṭi}{20}\right]\left(2 + \frac{2}{6}\right)$ and

True daily motion of the Moon = Mean motion of the Moon $\pm$ *gatiphalam*

If *MK* is within 6 *rāśis* from *Karka* (i.e., if the *mandakendra* (*MK*) is in II or III quadrant) add *gatiphalam* to the mean daily motion.

If *MK* is within 6 *rāśis* from *Makara* (i.e., if *MK* is in I or IV quadrant), subtract *gatiphalam* from the mean daily motion.

Example :

Mandakendra of the Moon $MK = 3^R\,25°12'17'' = 115°12'17''$

Bhuja of $MK = 180° - 115°\,12'\,17'' = 64°47'43'' \equiv BMK$

$\therefore$ *Koṭi* of $MK = 90° - BMK = 90° - 64°47'43'' = 25°12'17''$

$\therefore$ *Gatiphalam* of the Moon $= \left[\left(11 - \frac{Koti}{20}\right)\frac{Koti}{20}\right]\left(2 + \frac{2}{6}\right)$

$$= \left[\left(11 - \frac{25°12'17''}{20}\right)\frac{25°12'17''}{20}\right]\left(2 + \frac{2}{6}\right)$$

$$= 28'.640272 = 28'38''24''' \qquad \text{.......} \ (1)$$

Since $MK = 115°12'17''$ is in the II quadrant the *gatiphalam* is additive. Therefore, we have

true daily motion of the Moon = Mean motion of the Moon + *gatiphalam*

$$= 790'35''+28'38''24'''$$

$$\approx \mathbf{819'13''}$$

Remark : From the classical sine formula for the Moon, we have

$$\frac{\Delta n}{\Delta t} = \frac{b}{R}\cos M\left[\frac{\Delta L}{\Delta t} - \frac{\Delta A}{\Delta t}\right]$$

where A = Moon's apogee and its mean daily motion $\frac{\Delta A}{\Delta t} = 6'41''$

$b = 31°$, $R = 360°$, $\frac{\Delta L}{\Delta t} = 790'35''$, the Moon's mean daily motion

$M = BMK = 64°47'43''$, the bhuja of Mandrakendra

$$\frac{\Delta n}{\Delta t} = \frac{31}{360}\cos(64°47'43'')[790'35''-6'41'']$$

$$= 28'44''46''' \qquad \ldots\ldots (2)$$

We observe that the difference between (1) and (2) is less than $6''$.

***Śloka* 5** : In this *śloka* finding *palabhā* and *carakhaṇḍas* of a given place are explained as follows :

I. To find *palabhā* :

The day on which the true longitude of the *sāyana* (tropical) Sun becomes $0°0'0''$ (i.e. equinoctial day), determine the shadow of a 12 *aṅgula*

long cone (*śaṅku*) placed on a plane surface at the noon. This shadow length is called *palabhā* or *akṣabhā*. In other words, it is the shadow of the *śaṅku* at the equinoctial noon.

II. To find *carakhaṇḍas* :

Multiply *palabhā* by 10, 8 and $\frac{10}{3}$ respectively. We get three *khaṇḍas*. They are called *carakhaṇḍas* which are in *vikalās* (seconds of arc).

Example : *Palabhā* of Almora [Long. $79° E\, 40'$; Lat. $29° N\, 36'$;] = $6|47$ *aṅgulas*

The three *carakhaṇḍas* are

$$(6|47)\times 10\,,\quad (6|47)\times 8 \quad \text{and} \quad (6|47)\times\frac{10}{3}$$

$$= 67.8333,\quad 54.2666 \quad \text{and} \quad 22.61111$$

$$\approx \mathbf{68''},\quad \mathbf{54''} \quad \text{and} \quad \mathbf{23''}$$

Remark : The latitude ϕ of a place can be obtained from the *palabhā* of the place as follows :

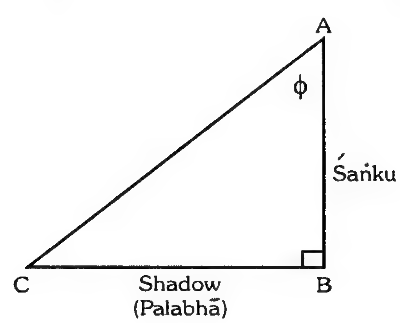

Fig. 2.2

In the right-angled Δ^{le} *ABC*, we have

$$\tan\phi = \frac{palabh\bar{a}}{sanku} = \frac{BC}{AB} = \frac{palabh\bar{a}}{12}$$

$\therefore$ *Palabhā* = 12 tan ϕ *aṅgulas*

From this we have

$$\phi = \tan^{-1}[Palabh\bar{a}/12]$$

For example, the *palabhā* of Almora ($\phi = 29°36'$) is 12 $\tan\phi$ $= 12\tan(29°36') = 6^{ang}\ 49^{prat}$.

Note : 1 *aṅgula* = 60 *Pratyaṅgulas.*

***Śloka* 6** : This *śloka* gives the method of finding *cara* correction.

It is as follows :

(i) Find *sāyana* Ravi (tropical Sun).

(ii) Find *bhuja* of the *sāyana* Sun. Express it in *rāśis, amśas, kalās* and *vikalās.*

(iii) The number which represents *rāśi* gives the number of elapsed *khaṇḍas.*

(iv) Find the *bhogya khaṇḍa* (i.e., *khaṇḍa* to be covered) and multiply it by the remaining *amśas* etc.

(v) Divide the result of (iv) by 30.

(vi) Add the result of (v) to the elapsed *khaṇḍas*.

This gives the *cara in seconds* ($''$) of arc .

Note : During the day time

(i) if *sāyana* Ravi (*SR*) is within 6 *rāśis* from *Meṣa* (i.e., $0^\circ < SR < 180^\circ$), then *cara* is negative.

(ii) if *sāyana* Ravi (*SR*) is within 6 *rāśis* from *Tulā* (i.e., $180^\circ < SR < 360^\circ$) *cara* is positive.

During the night time

(i) *cara* is positive if $0^\circ < SR < 180^\circ$

(ii) *cara* is negative if $180^\circ < SR < 360^\circ$.

Example : *Palabhā* of Kāśī : 5 *aṅgulas* 45 *pratyaṅgulas* = $5|45$ *aṅgulas*

The three *carakhaṇḍas* are

$$(5|45)\times 10\,, \quad (5|45)\times 8 \quad \text{and} \quad (5|45)\times\frac{10}{3}$$

$$= \mathbf{57''}, \quad \mathbf{46''} \quad \text{and} \quad \mathbf{19''}$$

Suppose *sāyana* Ravi = $1^R\,23^\circ 54' 10''$, *bhuja* = $1^R\ 23^\circ\ 54'\ 10''$

The number 1 in the *raśi* position implies that the number of elapsed *khaṇḍas* = 1

$\therefore$ Elapsed *khaṇḍa* = $57''$

Bhogya khaṅḍa = $46''$

Remaining *aṁśas* etc. = $23°54'10''$

Now, $\frac{23°54'10''}{30°} \times 46'' = \frac{1099}{30} \approx 36''$

$\therefore$ *Cara* = Elapsed *khaṇḍa* + $36''$

$= \mathbf{57''+36''=93''}$

Since *sāyana* Ravi is within 6 *rāśis* from *Meśa*, the *cara* is negative.

$\therefore$ *cara* corrected *nirayaṇa* Sun = $1^R\, 5°44'10''-93''$

$= \mathbf{1^R\, 5°\, 42'37''}$

(the *ayanāmśa* = $18°\ 10'$)

Remark : The latitude of Kaśī (Vārāṇāsī) is $\phi = 25°N\, 19'$.

Therefore, *palabhā* = $12 \tan \phi = 12 \tan\ 25°19' = 5|40$ *aṅgulas*

However, commentator Viśvanātha has taken its value as $5|45$ *aṅg.*

The *carakhaṇḍas* are

$(5|40)\times 10$, $(5|40)\times 8$ and $(5|40)\times \frac{10}{3}$

i.e., $56''.766$, $45''.41$ and $18''.92$

The elapsed *khaṇḍa* = $56''.766$

Bhogyakhaṇḍa = $45''.41$

Remaining *amśas* etc. = $23°54'10''$

Now, $\frac{23°54'10''}{30°} \times 45''.41 = 36''.181$

$\therefore$ *Cara* = Elapsed *khaṇḍa* + $36''.181$

$= 56''.77 + 36''.181 = 92''.95$

Therefore , *cara* corrected *nirayaṇa* Sun

$= 1^R\ 5°44'10'' - 92''.95 \approx 1^R\ 5°\ 42'37''$.

***Śloka* 7** : This *ślōka* explains the method of applying the *cara*, *bhujāntara* and *deśāntara* corrections to the Moon.

(1) *Cara* correction for the Moon :

Subtract $\left(\frac{2 \times Cara}{9}\right)'$ from the mean position of the Moon to get the *cara* corrected Moon. Here, *cara* must be taken in minutes (′) of arc.

i.e., *Cara* corrected Moon = Mean Moon $- \left(\frac{2 \times Cara}{9}\right)'$

(2) *Bhujāntara* correction for the Moon : (using *mandaphala* of the Sun).

Divide the *mandaphala* of the Sun by 27. The result will be in degrees, minutes of arc. Add this to the *cara* corrected Moon. That is

Bhujāntara corrected Moon

$= \quad \{Cara \text{ corrected Moon}\} + \frac{mandaphala\ of\ the\ Sun}{27}$

(3) *Deśāntara* correction for the Moon :

Find the *yojanas* of the place from the Ujjayinī meridian (*rekhā*). Divide it by 6 to get the *deśāntara* correction in *kalās* (minutes of arc)(approx.).

Note : In modern astronomy, the equivalent of *deśāntara* is given by $\frac{(\lambda - \lambda_0)}{360}$ day where λ and λ_0 are respectively the longitudes of a place and of the central meridian (in degrees). Let ϕ be the terrestrial latitude of a place so that the R sine of its co-latitude CP is $3438 \sin(90^\circ - \phi)$. The diameter of the earth is taken as 1600 *yojanas* (i.e., about 8000 miles). The maximum (equitorial) circumference, $MC = 2\pi(800) = 1600\,\pi$ *yojanas*.

The corrected circumference CC at a place is given by

$$CC = \frac{MC \cdot CP}{343\,8'}.$$

From these, we get

$$Deśāntara \text{ correction} = \frac{(\lambda - \lambda_0)^\circ}{360^\circ} \cdot \frac{MC \cdot CP}{3438} \cdot \frac{DM}{CC}$$

$$= \frac{(\lambda - \lambda_0)^\circ}{360^\circ} \cdot \left(\frac{MC \cdot CP}{3438}\right) \cdot \frac{DM}{\left(\frac{MC \cdot CP}{3438}\right)}$$

$$= \frac{(\lambda - \lambda_0)^\circ}{360^\circ} \cdot DM$$

where DM is the daily motion of a planet.

Grahalāghavam gives the expression for the *deśāntara* correction in *kalās* as one-sixth of the distance in *yojanas* of a place from Ujjayinī. The commentator Viśvanātha has given the distance of Kāśī from the central meridian as 65 *yojanas*.

Let $r = 4000$ miles $\approx$ 800 *yojanas* (Fig. 2.3).

We have $\cos\phi = \dfrac{r_1}{r}$

$\therefore\ r_1 = (800\ \cos\phi)$ *yojanas*

The circumference of the small circle through a place A is given by $2\pi r_1 = (1600\,\pi)\cos\phi$ *yojanas.*

Taking the circumference of the small circle as $360°$, we have

$(1600\,\pi\cos\phi)$ *yojanas* $= 360°$

$\therefore\ x$ *yojanas* $= 360\ x / 1600\ \pi\cos\phi$

$$\approx \frac{(0.0716)x}{\cos\phi} \text{ degrees.}$$

$$= \frac{(0.0716)x}{15\ \cos\phi} \text{ in hours}$$

or $\dfrac{(0.0716)x}{6\ \cos\phi}$ in *ghaṭīs.*

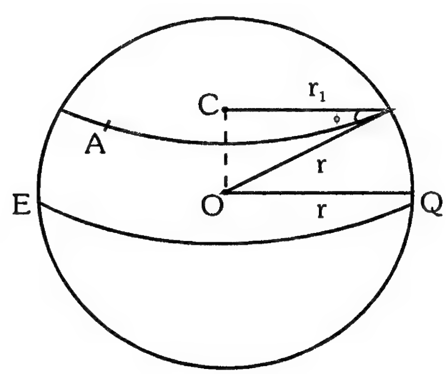

Fig. 2.3

For example, for the Moon, at Kāśī,

Deśāntara correction = $\dfrac{(0.0716)64}{6\cos(25^\circ 36')} \times \dfrac{790'.35''}{60} \approx 11'9''$ .... (1)

Now, according to the *Grahalāghavam*, approximately,

Deśāntara correction = $\dfrac{1}{6}$ (distance in *yojanas*)

$$= \frac{1}{6} \times 64 \approx 10'40''$$ .... (2)

The difference between (1) and (2) is just about $29''$.

Example : Mean Moon = $6^R\ 20^\circ\ 10'24''$

Candrocca = $10^R\ 14^\circ\ 54'43''$

Cara = $93''$

(i) ***Cara* correction for the Moon :-**

Cara corrected Moon = Mean Moon $- \dfrac{2 \times Cara}{9}$

$$= 6^R\ 20^\circ\ 10'\ 24'' - \frac{2 \times 93'}{9}$$

(taking *cara* as in minutes of arc).

$$= 6^R\ 20^\circ\ 10'24'' - 20'40''$$

$$= \mathbf{6^R\ 19^\circ\ 49'44''}$$

(ii) *Bhujāntara* correction for the Moon :

Mandaphala of the Sun = $1^\circ\, 30'\, 28''$ (additive)

Bhujāntara corrected Moon = *Cara* corrected Moon +

$$\frac{\textit{mandaphala} \text{ of the Sun}}{27} = 6^R\; 19^\circ\, 49'\, 44'' + \frac{1^\circ\, 30'\, 28''}{27}$$

$$= 6^R\; 19^\circ\, 49'\, 44'' + 0^\circ\, 3'\, 21''$$

$$= \mathbf{6^R\; 19^\circ\, 53'\, 05''}$$

(iii) *Deśāntara* correction for the Moon :

Distance of Kāśī from *Rekhāpura* in *yojanas* = 64

$\therefore$ *Deśāntara* correction $\approx \left(\dfrac{64}{6}\right)' = 10'\, 40''$

$\therefore$ *Deśāntara* corrected Moon

= *Bhujāntara* corrected Moon + *Deśāntara* correction

$= 6^R\; 19^\circ\, 53'\, 05'' - 10'\, 40'' \quad = \mathbf{6^R\; 19^\circ\, 42'\, 25''}$

Now, we have

The Moon after all the three corrections = $6^R\; 19^\circ\, 42'\, 25''$

***Manda* correction for the Moon :**

Candrocca = $10^R\; 14^\circ\, 54'\, 43''$

The thrice corrected Moon = $6^R\ 19°\ 42'\ 25''$

MK ≡ *Mandakendra* = $3^R\ 25°\ 12'\ 18''$

Bhuja of *MK* = $180° - 3^R\ 25°\ 12'\ 18''$

$= 64°\ 47'\ 42''$

Mandaphala of the Moon = $\dfrac{\left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6}}{56 - \dfrac{\left[\left(30 - \dfrac{MK}{6}\right)\dfrac{MK}{6}\right]}{20}}$ [from *Śloka* 3]

$$= \frac{\left[30 - \left(\dfrac{64°\ 47'\ 42''}{6}\right)\right]\left(\dfrac{64°\ 47'\ 42''}{6}\right)}{56 - \dfrac{\left[\left(30 - \dfrac{64°\ 47'\ 42''}{6}\right)\dfrac{64°\ 47'\ 42''}{6}\right]}{20}}$$

$= 4°\ 33'\ 38''$

Since *MK* = $3^R\ 25°\ 12'\ 18'' < 180°$, the *mandaphala* is additive.

∴ True Moon = Mean Moon (after three corrections) + *mandaphala*

$= 6^R\ 19°\ 42'\ 25'' + 4°\ 33'\ 38''$

$= 6^R\ 24°\ 16'\ 03''$ = **204° 16′ 03″**.

***Ślokas* 8 and 9** : These two *ślokas* give the method of finding *tithi*, *nakṣatra*, *yoga* and *karaṇa*.

(1) To find *tithi* :

(i) Subtract the true longitude of the Sun from the true longitude of the Moon.

(ii) Divide the result of step (i) by 12. This (quotient) gives the number of elapsed *tithis*.

(iii) The remainder gives the elapsed part of the running *tithi*. It will be in degrees, min., etc.

(iv) Subtracting the elapsed part of the running *tithi* from 12, we get *bhogyāmśa* (i.e., the portion to be covered) of the running tithi in degrees.

(v) Convert the result of step (iii) into seconds of arc (*vikalās*).

(vi) Convert the result of step (iv) into seconds of arc (*vikalās*).

(vii) Consider the difference between true daily motions of the Moon and the Sun and convert it into seconds of arc (*vikalās*).

(viii) Multiply the result of step (v) by 60 and divide by that of step (vii). This gives the elapsed *ghaṭikās* of the running *tithi*.

(ix) Multiply the result of step (vi) by 60 and divide it by that of step (vii). This gives the *eṣyaghaṭikā* (i.e., *ghaṭikās* to be covered) of the running *tithi*.

***Tithi* :**

In the course of a lunar month, from a new moon to the next new moon, the shape and size of the Moon changes from day to day. On an *amāvāsyā* day (newmoon day) the Moon is invisible as in *A*, (see Fig. 2.4). On the next day, a very thin "crescent" Moon *B* is visible, if the sky is clear, soon after the sunset in the western horizon.

On the succeeding days of the *śukla pakṣa* the brighter or visible part of the Moon keeps on growing until it is half (*C*) between the 7th and

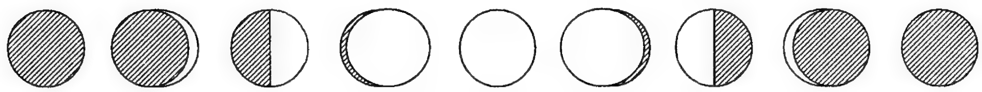

Fig. 2.4

8th day the after the new moon. Also, each day, the Moon keeps moving up in the sky at sunset since it moves farther from the Sun at the rate of about 12° per day. When the phase of the Moon is half, it will be midway in the sky between the eastern and the western horizons. Then, each succeeding day the brighter part of the Moon grows more than half when it is said to be *gibbous*, *D*. At the end of the *śukla pakṣa*, the Moon will be fully visible, *E*, when the *kṛṣṇa pakṣa* (dark half of the month) commences.

In the *kṛṣṇa pakṣa*, the phases of the Moon diminish (or wane) in the reverse order. From the full moon upto the 7th or 8th day, more than half the Moon is bright when it is said to be *gibbous*, *F*. Then, between *saptamī* and *aṣṭamī*, the Moon will be half (*G*). The bright portion of the Moon goes on decreasing till it is *crescent* (*H*) again, a day before the new moon day. At the end of the *kṛṣṇa pakṣa* the Moon is totally invisible on the new moon day, *I*.

The lunar month is divided into 30 parts called *tithis*. The bright half has 15 *tithis* and so too the dark half. The duration of a *tithi* is the time taken by the Moon to move 12° relative to the Sun. The durations of different *tithis* are not equal. In a *pakṣa* (fortnight), starting from the new moon or the full moon, there are 15 *tithis* (Table 2.2) :

Table 2.2 *Tithis*

1. *Pratipat*	6. *Ṣaṣṭī*	11. *Ekādaśī*
2. *Dvitīya*	7. *Saptamī*	12. *Dvādaśī*
3. *Tṛtīya*	8. *Aṣṭamī*	13. *Trayodaśī*
4. *Caturthī*	9. *Navamī*	14. *Caturdaśī*
5. *Pañcamī*	10. *Daśamī*	15. *Pūrṇimā or Amāvāsyā*

Therefore,

$$Tithi = [\text{Longitude of the Moon} - \text{Longitude of the Sun}] / 12^\circ$$

where both the longitudes are in degrees.

The quotient part indicates the number of *tithis* completed during the lunar month, and hence the (quotient + 1) gives the currently running *tithi*. If the running *tithi* is less than 15, then it is of the *śukla pakṣa* (bright fortnight). If the *tithi* is greater than 15, then subtract 15 from that number and the remainder gives the running *tithi* in the *kṛṣṇa pakṣa*.

If the running *tithi* is 15, then it is a *pūrṇimā* (full moon) day and if it is 30, the day is an *amāvasyā* (new moon day).

Note : If the longitude of the Moon is less than that of the Sun then add 360° to avoid the negative sign, and then divide it by 12 to get the *tithi*.

Example :

True Sun $= 1^R\ 5^\circ\ 42'\ 37''$

True Moon $= 6^R\ 24^\circ\ 16'\ 3''$

(i) Moon – Sun $= 6^R\ 24^\circ\ 16'\ 3'' - 1^R\ 5^\circ\ 42'\ 37''$

$= 5^R\ 18^\circ\ 33'\ 26''$

$= 168^\circ\ 33'\ 26''$

(ii) Now, $\dfrac{168^\circ\ 33'\ 26''}{12} = 14 + \dfrac{0^\circ\ 33'\ 26''}{12^\circ}$

Quotient = 14; Remainder = $0^\circ\ 33'\ 26''$

Therefore, the number of elapsed *tithis* is 14 and the running *tithi* is 15th. That is the running *tithi* is *Pūrṇimā*.

(iii) Remainder = $0^\circ\ 33'\ 26''$ implies that the elapsed part of the running *tithi*, viz. *Pūrṇimā* = $0^\circ\ 33'\ 26''$.

(iv) Now, $12^\circ - 0^\circ 33' 26'' = 11^\circ 26' 34''$, the *bhogyāmśa*.

(v) The elapsed part $0^\circ 33' 26'' = 2006''$ (*vikalās*), the *gata*.

(vi) The balance, $11^\circ 26' 34'' = 41194''$ (*vikalās*), the *eṣya*.

(vii) True daily motion of the Moon – True daily motion of the Sun

$$= 819' 0'' - 57' 36''$$

$$= 761' 24'' = 45684''$$

(viii) Elapsed *ghaṭikās* of the running *tithi* = $\dfrac{2006 \times 60}{45684}$

$$= 2^{gh}\ 38^{vgh}$$

(ix) *Eṣyagaṭikā* of the running *tithi* = $\dfrac{41194 \times 60}{45684}\ gh$

$$= 54^{gh}\ 6^{vgh}$$

Thus, we have

Elapsed *ghaṭikās* of *pūrṇimā* = $2^{gh}\ 38^{vgh}$

Eṣya ghaṭikās (i.e., balance *ghaṭikās*) of *pūrṇimā* = $54^{gh}\ 6^{vgh}$

$\therefore$Total duration of the *tithi* = $2^{gh}\ 38^{vgh} + 54^{gh}\ 06^{vgh} = 56^{gh}\ 44^{vgh}$

(3) To find *nakṣatra* :

(i) Find the true longitude of the Moon for the given time. Convert it into *kalās* (minutes of arc).

(ii) Divide the result ofstep (i) by 800 *kalās*.

(The extent of a *nakṣatra* = $13^\circ\ 20' = 800'$)

(iii) The quotient in step (ii) gives the number of elapsed *nakṣatras* [see Table 2.3].

(iv) The remainder in step (ii) gives the elapsed part of the running *nakṣatra*.

(v) Subtract the result of step (iv) from 800. This gives *eṣya* (i.e., *kalās* to be covered in the running *nakṣatra*). Express the results of (iv) and (v) in *vikalās*.

(vi) Consider the true daily motion of the Moon and express it in *vikalās* (seconds of arc).

(vii) Multiply the result of step (iv) by 60 and divide it by that of step (vi). This gives the (elapsed) *ghaṭikās* of the running *nakṣatra*.

(viii) Multiply the result of step (v) by 60 and divide it by the result of step (vi). This gives *eṣya ghaṭikās* of the running *nakṣatra* (i.e., *ghaṭikās* to be covered in the running *nakṣatra*).

(ix) The sum of the results of steps (vii) and (viii) gives the total duration of the running *nakṣatra*.

Table 2.3 *Nakṣatras* and their range of *nirayaṇa* longitudes

No.	*Nakṣatra*	From	To
1.	*Aśvinī*	0°0′	13°20′
2.	*Bharaṇī*	13°20′	26°40′
3.	*Kṛttikā*	26°40′	40°00′
4.	*Rohiṇī*	40°00′	53°20′
5.	*Mṛgaśira*	53°20′	66°40′
6.	*Ārdrā*	66°40′	80°00′
7.	*Punarvasu*	80°00′	93°20′
8.	*Puṣya*	93°20′	106°40′
9.	*Āśleṣā*	106°40′	120°00′
10.	*Makhā (or Maghā)*	120°00′	133°20′
11.	*Pubba (Pūrva Phālguṇī)*	133°20′	146°40′
12.	*Uttarā (Uttara Phālguṇī)*	146°40′	160°00′
13.	*Hasta*	160°00′	173°20′
14.	*Cittā* (or Citrā)	173°20′	186°40′
15.	*Svātī*	186°40′	200°00′
16.	*Viśākhā*	200°00′	213°20′
17.	*Anurādhā*	213°20′	226°40′
18.	*Jyeṣṭhā*	226°40′	240°00′
19.	*Mūlā*	240°00′	253°20′
20.	*Pūrvāṣādhā*	253°20′	266°40′
21.	*Uttarāṣādhā*	266°40′	280°00′
22.	*Śravaṇa*	280°00′	293°20′
23.	*Dhaniṣṭhā*	293°20′	306°40′
24.	*Śatabiṣaj*	306°40′	320°00′
25.	*Pūrvābhādrā*	320°00′	333°20′
26.	*Uttarābhādrā*	333°20′	346°40′
27.	*Revatī*	346°40′	360°00′

Example :

(i) True *nirayaṇa* Moon $= 6^R\ 24^\circ\ 15'\ 03'' \qquad = 12255'\ 03''$

(ii) $$\frac{12255'\,3''}{800'} = 15 + \frac{255'\,03''}{800'}$$

(iii) The quotient = 15 implies that the number of elapsed *nakṣatras* is 15 and the 16th *nakṣatra*, *Viṣākhā* (see Table 2.3) is running.

(iv) The remainder = $255'03''$ implies that

the elapsed part of the running *nakṣatra* (*Viśākhā*) = $255'03'' = 15303''$

(v) Now, $800' - 255'03'' = 544'57'' = 32697''$ (*vikalās*)

(vi) True daily motion of the Moon = $819'0'' = 49140''$

(vii) We have $\dfrac{15303 \times 60}{49140} = 18.684982^{gh} = 18^{gh}\ 41^{vgh}$

i.e., elapsed (gata) *ghaṭikās* of *Viśākhā* $\approx 18^{gh}\ 41^{vgh}$

(viii) $\dfrac{32697 \times 60}{49140} = 39.923077^{gh} \approx 39^{gh}\ 55^{vgh}$

i.e., balance (*eṣya*) *ghaṭikās* of *Viśākhā* = $39^{gh}\ 55^{vgh}$

(ix) $\therefore$ Duration of *Viśākhā* = $18^{gh}\ 41^{vg} + 39^{gh}\ 55^{vgh}$

$= 58^{gh}\ 36^{vgh}.$

(3) The find *karaṇa* :

(i) Multiply the number of elapsed *tithi* by 2 and divide it by 7. This gives the *karaṇa* starting with *Bava*.

A half *tithi* is called a *karaṇa* i.e., it is of an angular distance of 6° between the Sun and the Moon. There are totally 11 *karaṇas*. Of these 4 are inmovable (*sthira*) and 7 are movable (*cara*). In particular, 4 half-*tithis* viz. the second half of *kṛṣṇa pakṣa caturdaśī*, two halves of *amāvāsyā*, and the first half of the *śukla pratipat* are the *sthira*, *karaṇas* named as *Śakuni*, *Catuṣpāda*, *Nāga* and *Kimstughna* in that order.

Then from the second half of the *śukla pratipat* onwards we have the movable (*cara*) *karaṇas* viz. *Bava, Bālava, Kaulava, Taitila, Gara, Vaṇij* and *Viṣṭi* (or *Bhadra*) in that order repeating the cycle 8 times.

Example 1 : Elapsed *tithi* = 14. Now, $2 \times \frac{14}{7} = 4$ (quotient), remainder =0

i.e., the last *karaṇa* in the cycle of 7 *karaṇas* (having completed 4 cycles) namely *Viṣṭi* (or *Bhadra*).

Example 2 : March 21, 1990 at $5^h\ 30^m$ a.m. (IST). We have true Moon, $M = 262°10'0''$ and the true Sun, $S = 336°23'13''$. Therefore, $(M-S) = 262°10' - 336°23'13'' = 285°46'47''$ /(after adding $360°$ to avoid the negative sign).

Now, $(M-S)/6 = 47.629953$.

Since this number is greater than 7, removing the multiples of 7, we get the remainder 5.629953. The integral part of the number is 5. Counting 5 starting with *Bava* in the list of moving (*cara*) *karaṇas*, we get *Gara* as the running *karaṇa*.

Note : Since the cycle of 7 cara *karaṇas* starts with the *second half* (and not the first half) of *śukla pratipat*, the integral part of the quotient represents the *running* (and the not the elapsed) *karaṇa*.

(4) To find yoga :

Add the *nirayaṇa* longitudes of the Sun and the Moon and convert the sum into *kalās* (minutes of arc). Divide this sum by $800'$. In the thus obtained result the integer part gives the elapsed *yoga* and the fractional part represents the elapsed portion of the running (current) *yoga* (see Table 2.4).

Table 2.4 *Yogas*

There are 27 *yogas* as listed below :

1.	*Viṣkambha*	15.	*Vajra*
2.	*Prīti*	16.	*Siddhi*
3.	*Āyuṣmān*	17.	*Vyatīpāta*
4.	*Saubhāgya*	18.	*Varīyān*
5.	*Śobhana*	19.	*Parigha*
6.	*Atigaṇḍa*	20.	*Śiva*
7.	*Sukarmā*	21.	*Siddha*
8.	*Dhṛti*	22.	*Sādhya*
9.	*Śūla*	23.	*Śubha*
10.	*Gaṇḍa*	24.	*Śukla*
11.	*Vṛddhi*	25.	*Brahma*
12.	*Dhruva*	26.	*Indra*
13.	*Vyāghāta*	27.	*Vaidhṛta*
14.	*Harṣaṇa (or Vaidhṛti)*		

Note : If the sum of the *nirayaṇa* longitudes of the Sun and the Moon (in degrees) exceeds 360°, then subtract 360° from the sum, convert into minutes and then divide that figure by 800.

Example 1 : Sum of the longitudes of the Sun and the Moon = $7^R\,29^\circ\,57'\,40'' = 14397'\,40''$. Dividing this by $800'$, we get 17.9970. This means 17 *yogas* have elapsed and the 18th one viz. *Varīyān* is currently running.

Example 2 : On March 21, 1990 at $5^h\ 30^m$ a.m. (IST), the *nirayaṇa* longitude of the Sun, $S = 336^\circ\,23'$ and that of the Moon, $M = 262^\circ\ 10'$ (neglecting seconds of arc). $\therefore\ S + M = 598^\circ\,33'$. Since the sum exceeds 360°, subtracting 360°, we get $S + M = 238^\circ\,33'$. Converting into *kalās*, we have $S + M = 14{,}313'$. Dividing this by $800'$, we get 17.89125. This means that the 17^{th} *yoga* (*Vyatīpāta*) is over and the 18^{th} one viz. *Varīyān* is running.

CHAPTER 3

PAÑCATĀRĀ SPAṢṬĀDHIKĀRA
(True Positions of Star-Planets)

***Ślokas* 1 to 5** : In the first five *ślokas* the *Śīghraphalas* of the five *tārāgrahas* viz. Kuja, Budha, Guru, Śukra and Śani are explained. The *Śīghrāṅkas* of the five planets at intervals of 15^0 from 0^0 to 180^0 of the *Śīghrakendras* are given as tabulated below :

Table 3.1 *Śīghrāṅkas* of *Tārāgrahas*

Planets	0	1	2	3	4	5	6	7	8	9	10	11	12
Kuja	0	58	117	174	228	279	325	365	393	400	368	249	0
Budha	0	41	81	117	150	178	199	212	212	195	155	89	0
Guru	0	25	47	68	85	98	106	108	102	89	66	36	0
Śukra	0	63	126	186	246	302	354	402	440	461	443	326	0
Śani	0	15	28	39	48	54	57	57	53	45	33	18	0

***Śloka* 6** : In the case of the superior planets viz. Kuja, Guru and Śani, the *Śīghrakendra* = *Śīghrocca* – mean planet ≡ m, say,

where *Śīghrocca* is the mean Sun for all the three planets.

To find the *Śīghrāṅka* of a planet we have the following procedure :

(1) (a) Divide the *Śighrakendra* (if $m < 180^0$) by 15 and find the quotient q (*aṅka*) and let the remainder be r.

(b) If $m > 180^0$ subtract m from 360^0 (i.e. find $360^0 - m$) and divide $(360^0 - m)$ by 15 to get q (*aṅka*) and the remainder r. We call $(360^0 - m)$ as *bhuja* for convenience.

(2) Find the *Śīghrāṅkas*, from Table 3.1, corresponding to the quotient (i.e., from the column headed by q against the planet and also from the next column [i.e., $(q+1)^{th}$ column] and take the difference between the latter and the former *Śigrāṅkas*.

(3) Multiply the above difference of *Śīghrāṅkas* by the remainder r [obtained in (1) above] and divide by 15.

(4) Add the value obtained in (3) to the *Śighrāṅka* obtained in item (2) above under the column headed by q. The result obtained by dividing by 10 is the required *Śīghraphala*. Note that the difference between two successive columns (headed by $q+1$ and q) may be negative also. In that case, subtract the result of (3) from that of (2) under q.

(5) If the *Śighrakendra* m is less than 180^0, the *Śighraphala* is posi tive. On the otherhand , if $m > 180^0$, then the *Śīghraphala* is negative.

Example : Suppose, on a certain day, mean Kuja = $11^R\,3^\circ\;53'25'' \equiv MP$

and mean Sun = $11^R\,17^\circ\,32'53'' \equiv MS$ which is the *Śīghrocca* of Kuja.

$\therefore$ *Śīghrakendra* (i.e., *Śīghra* anomaly) of Kuja = *Śīghrocca* – mean Kuja

$= MS - MP = 11^R\,17^\circ\,32'53'' - 11^R\,3^\circ\,53'25'' = 0^s\,13^\circ\,39'\,28'' \equiv SK$.

Here, $SK < 180^0$. We shall now find the *Śīghraphala* :

(1) Dividing SK by 15, quotient $q = 0$ (*aṅka*) and remainder $r =$ $13^\circ\,39'28''$.

(2) From Table 3.1, the entries against Kuja under the columns headed by q and $q+1$ i.e., 0 and 1 are respectively 0 and 58. Therefore,

the difference between the above *Śīghrāṅkas* = 58 – 0 (i.e., the latter – the former) = 58.

(3) Multiplying the result of (2) by *r* [from (1)] and dividing by 15, we get $58 \times 13°39'28''/15 = 52°48'36''$.

Adding $52°\ 48'\ 36''$ to the entry under *q* i.e., to 0 we get $52°\ 48'\ 36''$. Dividing the above *Śīghrānka* by 10, we get $5°16'52'' \equiv SE$, *Śīghraphala*.

5) Since $m < 180^0$, the *Śīghraphala* is additive.

According to the *Grahalāghavam*, we get the true position of a *tārāgraha*, from its mean position, by successively applying two types of corrections viz.the *Śīghra* and the *Manda samskāras* to be explained shortly.

***Ślokas* 7 and 8** : In these two *ślokas* the *Mandāṅkas* of the *tārāgrahas* are given as shown in the following table :

Table 3.2. *Mandāṅkas*

Planets	0	1	2	3	4	5	6
Kuja	0	29	57	85	109	124	130
Budha	0	12	21	28	33	35	36
Guru	0	14	27	39	48	55	57
Śukra	0	06	11	13	14	15	15
Śani	0	19	40	60	77	89	93

According to the *Grahalāghavam*, the *Mandoccas* of the five star-planets are as follows :

Table 3.3. *Mandoccas* of planets

Planets	*Mandoccas*
Kuja	$4^R = 120^0$
Budha	$7^R = 210^0$
Guru	$6^R = 180^0$
Śukra	$3^R = 90^0$
Śani	$8^R = 240^0$

Mandakendra of Planet = *Mandocca* – Mean Planet.

***Śloka* 9** : The method of finding the *Mandaphala* in the case of the five star-planets is explained as follows :

(i) Divide the *bhuja* of the *Mandakendra* by 15 and find the quotient q. Let the remainder be r.

(ii) Find the *Mandāṅka* from Table 3.2 corresponding to the quotient (i.e., from the column headed by q against the planet). Also find the next *Mandāṅka* [i.e., $(q + 1)^{th}$ column] and take the difference between the latter and the former *Mandāṅkas.*

(iii) Multiply the above difference with the remainder r (obtained in step (i) above) and divide by 15.

(iv) If the latter *Mandāṅka* is less than the former *Mandāṅka*, add the result of step (iii) to the latter *Mandāṅka.*

If latter *Mandāṅka* is greater than the former *Mandāṅka*, subtract the result of step (iii) from the latter *Mandāṅka.*

(v) Divide the result of step (iv) by 10 to obtain the *Mandaphala*.

Note : If *Mandakendra* (*MK*) is less than 180^0, the *Mandaphala* is positive. On the other hand, if $MK > 180^0$, then the *Mandaphala* is negative.

Example : Suppose on a certain day,

Mean Kuja $= 11^R\, 3°53'25''$

Mandocca of Kuja $= 4^R$

MK , *Mandakendra* = *Mandocca* – Mean Kuja

$= 4^R - 11^R\, 3°53'25''$

$= 146°6'35''$

Bhuja of *MK* $= 180° - 146°6'35''$

$= 33°53'25''$

Now, $\dfrac{33°53'25''}{15} = 2 + \dfrac{3°53'25''}{15}$

Here, quotient $q = 2$, remainder $r = 3°53'25''$

From Table 3.2, we have :

The entry against Kuja under the column headed by 2,

Gatāṅka = 57.

The entry against Kuja under the column headed by $(q + 1)$ i.e., 3,

Eṣyāṅka = 85.

Difference = 85 – 57 = 28.

$$\text{Now, } \frac{28 \times 3^\circ 53' 25''}{15} + 57 = 64^\circ 15' 42''$$

$$\therefore \textit{Mandaphala} = \frac{64^\circ 15' 42''}{10} = 6^\circ 25' 34''$$

Since $MK < 180^0$, the *Mandaphala* is positive.

***Śloka* 10** : The method of applying the *Mandaphala* and the *Śīghraphala* to attain true position of a planet is explained as follows :

(i) Find the *Śīghraphala* as explained earlier using mean planet (obtained from *Ahargaṇa*). Add (or subtract, as the case is) half of the *Śīghraphala* to (or from) the mean planet. This gives the *half-Śīghra* corrected planet.

(ii) Find the *Mandaphala* for the *half-Śīghra* corrected planet. Add (or subtract, as the case is) *Mandaphala* to (or from) the mean planet (obtained from the *Ahargaṇa*) which gives the *Manda* corrected planet.

(iii) Find the second *Śīghrakendra* using the first *Śīghrakendra* and the *Mandaphala*.

Second *Śīghrakendra* = First *Śīghrakendra* $\pm$ *Mandaphala*.

(iv) Find the second *Śīghraphala* using the second *Śīghrakendra*.

(v) Add (or subtract, as the case is) the second *Śīghraphala* to (or from) the *Manda*-corrected planet. This gives the true planet.

Example : We shall find the true positions of the planets for the example considered earlier viz., Monday, May 15, 1612 (G).

I Finding true position of Kuja :

Mean Kuja = $9^R\,29°\,55'13''$

Śīghrocca of Kuja = Mean Sun = $1^R\,4°\,13'42''$

(1) First *Śīghra* correction :

SK ≡ *Śīghrakendra* of Kuja = *Śīghrocca* – Mean Kuja

$$= 1^R\,4°\,13'42'' - 9^R\,29°\,55'13''$$

$$= 94°\,18'29''$$

Now, $\dfrac{\textit{Śīghrakendra}}{15} = \dfrac{94°\,18'29''}{15} = 6 + \dfrac{4°\,18'29''}{15}$

so that $q = 6$ and $r = 4°\,18'29''$.

Therefore, from Table 3.1, we have

Gatāṅka = 325 and *eṣyāṅka* = 365

Their difference = 365 – 325 = 40

Now, $\dfrac{\text{Remainder} \times \text{difference}}{15} = \dfrac{4°\,18'29''}{15} \times 40 = 11|29|17$

Gatāṅka + $11|29|17 = 325 + 11|29|17$

$$= 336|29|17$$

Therefore, *Śīghraphala* = $\frac{336|29|17}{10} \approx 33|38|56$

The *Śīghraphala* is positive since $SK = 94° 18' 29'' < 180°$.

Half-*Śīghraphala* = $\frac{33° 38' 56''}{2} = 16° 49' 28''$

Therefore, the *half-Śīghra* corrected Kuja = Mean Kuja + Half-*Śīghraphala*

$$= 9^R 29° 55' 13'' + 16° 49' 28''$$

$$= 10^R 16° 44' 41''$$

(2) *Manda* correction :

Mandocca of Kuja = $4^R 0° 0'$.

Mandakendra (*MK*) of Kuja

= *Mandocca* – Half-*Śīghra* corrected planet

$$= 4^R 0° 0' - 10^R 16° 44' 41'' = 5^R 13° 15' 19''$$

Bhuja of $MK = 180° - 5^R 13° 15' 19'' = 16° 44' 41''$

Now, $\frac{16° 44' 41''}{15} = 1 + \frac{1° 44' 41''}{15}$

Here, quotient $q = 1$ and remainder $r = 1° 44' 41''$

From Table 3.2 we have

gatāṅka = 29, *eṣyāṅka* = 57

Difference = 57 – 29 = 28

Now, $\dfrac{28 \times 1|44|41}{15} + 29 = 33|15|22$

$\therefore$ *Mandaphala* = $\dfrac{33|15|22}{10} = 3|19|32$

Since *MK* < 180^0, the *Mandaphala M* is positive.

Manda corrected Kuja = Mean Kuja + *Mandaphala*

$= 9^R\, 29°55'13'' + 3°19'32'' = 10^R\, 03°14'45''$.

(3) Second *Śīghra* correction :

First *Śīghrakendra* $= 3^R\, 4°18'29''$

Mandaphala = $3°\, 19'\, 32''$

Second *Śīghrakendra* = First *SK* – *Mandaphala*

$= 3^R\, 4°18'29'' - 3°19'32''$

$= 3^R\, 0°58'57''$

$= 90°58'57''$

Now, $\dfrac{90°58'\,57''}{15} = 6 + \dfrac{0°58'\,57''}{15}$

i.e., quotient $q = 6$ and remainder $r = 0°\,58'\,57''$

From Table 3.1, *gatāṅka* = 325, *eṣyāṅka* = 365

Difference = 40 and

$$\frac{40 \times 0°\,58'\,57''}{15} + 325 = 327|37|12.$$

Therefore, second *Śīghraphala* = $\dfrac{327|37|12}{10} = 32°\,45'\,43''$

∴ True longitude of Kuja = *Manda* corrected Kuja + Second *Śīghraphala*

$$= 10^R\,03°14'\,45''{+}32°\,45'\,43'' = 11^R\,06°\,00'\,28'' = 336°\,00'\,28''$$

II Finding true longitude of Budha :

(1) First ***Śighra* correction :**

Mean Budha = Mean Sun $= 1^R\,4°\,13'\,42''$

Śīghrakendra of Budha $SK = 1^R\,17°\,14'\,50'' = 47°\,14'\,50''$

(*SK* of Budha is obtained in *Madhyamādhikāra* i.e., Ch. 1)

Now, $\dfrac{47°\,14'\,50''}{15} = 3 + \dfrac{2°\,14'\,50''}{15}$

i.e., quotient = 3 and remainder = $2°\,14'\,50''$;

From Table 3.1, *gatāṅka* = 117, *eṣyāṅka* = 150

and the differecnce = 33.

Now, $\dfrac{2^\circ\,14'\,50'' \times 33}{15} + 117 = 121|56|38$

$\therefore$ *Śīghraphala* = $\dfrac{121|56|38}{10} = 12^\circ\,11'\,40''$

Now, Half-*Śīghraphala* = $\dfrac{12^\circ\,11'\,40''}{2} = 6^\circ\,05'\,50''$

Half-*Śīghra* corrected Budha = Mean Budha + Half *Śīghraphala*

$= 1^R\;4^\circ\,13'\,42'' + 6^\circ\,05'\,50'' = 40^\circ\,19'\,32''$

(2) Manda correction :

Mandocca of Budha = $7^R = 210^\circ\,0'\,0''$

Mandakendra (*MK*) of Budha = *Mandocca* – Half-*Śīghra* corrected Budha

$= 210^\circ - 40^\circ\,19'\,32'' \quad = 169^\circ\,40'\,28''$

Bhuja of *MK* $= 180^\circ - 169^\circ\,40'\,28'' \quad = 10^\circ\,19'\,32''$

Now, $\dfrac{12 \times 10^\circ\,19'\,32''}{15} + 0 = 8|15|38$

Mandaphala $= \dfrac{8|15|38}{10} = 0^\circ\,49'\,34''$

Since *MK* $< 180^\circ$, *Mandaphala* is positive.

Manda corrected Budha $= 1^R\ 04°\ 13'\ 42'' + 0°\ 49'\ 34''$

$= 1^R\ 05°\ 03'16'' = 35°\ 03'16''$

(3) Second *Śīghra* correction :

First *Śīghrakendra* $= 47°\ 14'\ 50''$

Mandaphalam $= 0°\ 49'\ 34''$

Second *Śīghrakendra* = First *ŚK* – *Mandaphala*

$= 47°\ 14'\ 50'' - 0°\ 49'\ 34'' = 46°\ 25'\ 16''$

Now, $\dfrac{46°\ 25'\ 16''}{15} = 3 + \dfrac{1°\ 25'\ 16''}{15}$; quotient = 3 and remainder = $1°\ 25'\ 16''$

From Table 3.1, *gatāṅka* = 117, *eṣyāṅka* = 150, difference = 33

Now, $\dfrac{33 \times 1°\ 25'\ 16''}{15} + 117 = 120|7|35$

$\therefore$ *Śīghraphala* = $\dfrac{120|7|35}{10} = 12°\ 0'\ 46''$.

Since $SK < 180°$, *śīghraphala* is additive.

Therefore, we have

the true longitude of Budha = *Manda* corrected Budha + Second *Śīghraphala*

$= 1^R\ 05°\ 03'16'' + 12°\ 0'\ 46' = 47°\ 04'\ 02''$

III Finding true longitude of Guru :

(1) First *Śīghra* correction :

Śīghrocca of Guru = Mean Sun = $1^R\ 4^\circ\ 13'\ 42''$

Mean Guru = $4^R\ 8^\circ\ 15'17''$

First *Śīghrakendra* = *Śīghrocca* – Mean Guru

$= 1^R\ 4^\circ\ 13'\ 42'' - 4^R\ 8^\circ\ 15'17''$

$= 265^\circ\ 58'\ 25'' \equiv SK$

Since *Śīghrakendra* > 180° subtract it from 360°.

i.e., *Śīghrakendra* argument = $360^\circ - 265^\circ\ 58'\ 25''$

$= 94^\circ\ 01'\ 35''$

Now, $\dfrac{94^\circ\ 01'\ 35''}{15} = 6 + \dfrac{4^\circ\ 01'\ 35''}{15}$; quotient = 6, remainder = $4^\circ\ 01'\ 35''$

From Table 3.1, *gatāṅka* = 106, *eṣyāṅka* = 108, difference = 2

Now, $\dfrac{2 \times 4^\circ\ 01'\ 35''}{15^\circ} + 106 = 106|32|12$

First *Śīghraphala* = $\dfrac{106\ |32\ |12}{10} = 10^\circ\ 39'\ 13''$

Since *SK* = $265^\circ\ 58'\ 25'' > 180^\circ$, the *Śīghraphala* is negative.

Half-*Śīghraphala* = $\dfrac{-10^\circ\,39'\,13''}{2} = -5^\circ\,19'\,36''$

Half-*Śīghra* corrected Guru = Mean Guru + Half-*Śīghraphala*

$= 4^R\,8^\circ\,15'\,17'' + (-5^\circ\,19'\,36'') = 4^R\,8^\circ\,15'\,17'' - 5^\circ\,19'\,36''$

$= 4^R\,2^\circ\,55'\,41''$

(2) *Manda* correction :

Mandocca of Guru = 6^R

Mandakendra (*MK*) = *Mandocca* – Half-*Śīghra* corrected Guru

$= 6^R - 4^R\,2^\circ\,55'\,41'' = 1^R\,27^\circ\,4'\,19'' = 57^\circ\,4'\,19''$

Bhuja of *MK* = $57^\circ\,4'\,19''$

Now, $\dfrac{57^\circ\,4'\,19''}{15} = 3 + \dfrac{12^\circ\,4'\,19''}{15}$; quotient = 3, remainder = $12^\circ\,4'\,19''$

From Table 3.2, *gatāṅka* = 39, *eṣyāṅka* = 48, difference = 9

Now, $\dfrac{9 \times 12^\circ\,04'\,19''}{15} + 39 = 46|14|35$

Mandaphala = $\dfrac{46|14|35}{10} = 4^\circ\,37'\,27''$

The *Mandaphala* is positive since $MK < 180^\circ$.

Manda corrected Guru = Mean Guru + *Mandaphala*

$$= 4^R\ 8^\circ\ 15'17'' + 4^\circ\ 37'27'' = 4^R\ 12^\circ\ 52'44''$$

(3) Second *Śīghra* correction :

First *Śīghrakendra* = $265^\circ\ 58'25''$

Second *Śīghrakendra* = First *ŚK* – *Mandaphalam*

$$= 265^\circ\ 58'25'' - 4^\circ\ 37'27'' = 261^\circ\ 20'\ 58'' \equiv \acute{S}K$$

Bhuja of *SK* = $360^\circ - 261^\circ\ 20'58'' = 98^\circ\ 39'02''$

We have $\dfrac{98^\circ\ 39'\ 02''}{15} = 6 + \dfrac{8^\circ\ 39'\ 02''}{15}$; quotient = 6, remainder = $8^\circ\ 39'\ 02''$.

From Table 3.1, *gatāṅka* = 106, *eṣyāṅka* = 108, difference = 2

Now, $\dfrac{2\times 8^\circ\ 39'\ 02''}{15} + 106 = 107|9|12$

$\therefore$ *Śīghraphala* = $\dfrac{107|9|12}{10} = 10^\circ\ 42'55''$

Śīghraphala is negative because $SK > 180^\circ$.

$\therefore$ True longitude of Guru = *Manda* corrected Guru + *Śīghraphala*

$$= 4^R\ 12^\circ\ 52'44'' + (-10^\circ\ 42'55'') = 4^R\ 2^\circ\ 9'49'' = \mathbf{122^\circ\ 9'49''}$$

IV Finding true longitude of Śukra :

Śīghrakendra of Śukra = $3^R\ 5°\ 41'35'' = 95°\ 41'35''$ (from Ch. 1)

Mean Śukra = Mean Sun = $1^R\ 4°\ 13'\ 42''$

(1) First *Śīghra* correction :

ŚK of Śukra = $95°\ 41'35''$

We have $\dfrac{95°\ 41'35''}{15°} = 6 + \dfrac{5°\ 41'35''}{15°}$; quotient = 6, remainder = $5°\ 41'35''$

From Table 3.1, *gatāṅka* = 354, *eṣyāṅka* = 402, difference = 48

Now, $\dfrac{48 \times 5°\ 41'\ 35''}{15} + 354 = 372|12|58$

Śīghraphala = $\dfrac{372|12|58}{10} = +37°\ 13'18''$

Half-*Śīghraphala* = $\dfrac{37°\ 13'18''}{2} = 18°\ 36'39''$

Half-*Śīghra* corrected Śukra = Mean Śukra + Half-*Śīghraphala*

$$= 1^R\ 4°\ 13'\ 42'' + 18°\ 36'39'' = 1^R\ 22°\ 50'21'' = 52°\ 50'21''$$

(2) *Manda* correction :

Mandocca of Śukra = 3^R

Mandakendra of Śukra = *Mandocca* – Half-*Śighra* corrected Śukra

$$= 3^R - 52^\circ\, 50'\, 21'' \quad = 37^\circ\, 9'\, 39''$$

Bhuja of *MK* = $37^\circ\, 9'\, 39''$

We have $\dfrac{37^\circ\, 9'\, 39''}{15^\circ} = 2 + \dfrac{7^\circ\, 9'\, 39''}{15^\circ}$; quotient = 2, remainder = $7^\circ\, 9'\, 39''$.

From Table 3.2, *gatāṅka* = 11, *eṣyāṅka* = 13, difference = 2

Now, $\dfrac{2 \times 7^\circ\, 9'\, 39''}{15^\circ} + 11 = 11|57|17$

Manda corrected Śukra = Mean Śukra + *Mandaphalam*

$$= 1^R\, 4^\circ\, 13'\, 42'' + 1^\circ\, 11'\, 44'' = 1^R\, 5^\circ\, 25'\, 26'' \quad = 35^\circ\, 25'\, 26''$$

(3) Second *śīghra* correction

First *SK* = $95^\circ\, 41'\, 35''$

Second *Śīghrakendra* = First *SK* – *Mandaphala*

$$= 95^\circ\, 41'\, 35'' - 1^\circ\, 11'\, 44'' \quad = 94^\circ\, 29'\, 51''$$

We have $\dfrac{94^\circ\, 29'\, 51''}{15^\circ} = 6 + \dfrac{4^\circ\, 29'\, 51''}{15^\circ}$; quotient = 6, remainder = $4^\circ\, 29'\, 51''$.

From Table 3.1, *gatāṅka* = 354, *eṣyāṅka* = 402 and their difference = 48

Now, $\dfrac{48 \times 4^\circ\, 29'\, 51''}{15^\circ} + 354 = 368|23|31$

$\therefore$ *Śīghraphala* = $\dfrac{368|23|31}{10} = +36^\circ\, 50'\, 21''$.

$\therefore$ True position of Śukra = *Manda* corrected Śukra + *Śīghraphala*

$$=1^R\ 5^\circ\ 25'\ 25'' + 36^\circ\ 50'\ 21'' = \mathbf{72^\circ\ 15'\ 46''}$$

V Finding true longitude of Śani :

We have, from Chapter 1,

Mean Śani = $11^R\ 0^\circ\ 36'\ 45''$

Śīghrccca of Śani = Mean Sun = $1^R\ 4^\circ\ 13'\ 42''$

Śīghrakendra SK = *Śīghrocca* – Mean Śani

$$= 1^R\ 4^\circ\ 13'\ 42'' - 11^R\ 0^\circ\ 36'\ 45'' \ = 63^\circ\ 36'\ 57''$$

We have $\dfrac{63^\circ\ 36'\ 57''}{15^\circ} = 4 + \dfrac{3^\circ\ 36'\ 57''}{15^\circ}$; quotient = 4, remainder = $3^\circ\ 36'\ 57''$

From Table 3.1, *gatāṅka* = 48, *eṣyāṅka* = 54, difference = 6

Now, $\dfrac{6 \times 3^\circ\ 36'\ 57''}{15^\circ} + 48 = 49|26|47$

Śīghraphala = $\dfrac{49|26|47}{10} = +\ 4^\circ\ 56'\ 41''$

Half-*Śīghraphala* = $\dfrac{4^\circ\ 56'\ 41''}{2} = 2^\circ\ 28'\ 21''$

Half-*Śīghra* corrected Śani = Mean Śani + Half-*Śighraphala*

$$=11^R\ 0^\circ\ 36'\ 45'' + 2^\circ\ 28'\ 21'' \ = 11^R\ 03^\circ\ 05'\ 06''$$

2) *Manda* correction :

Mandocca = 8^R

Mandakendra MK = *Mandocca* – Half-*Śīghra* corrected Śani

$$= 8^R - 11^R\ 03^\circ\ 05'\ 05'' = 8^R\ 26^\circ\ 54'\ 55'' = 266^\circ\ 54'\ 55''$$

Bhuja of *MK* = $266^\circ\ 54'\ 55'' - 180^\circ = 86^\circ\ 54'\ 55''$

We have $\dfrac{86^\circ\ 54'\ 55''}{15^\circ} = 5 + \dfrac{11^\circ\ 54'\ 55''}{15^\circ}$; quotient = 5, remainder = $11^\circ\ 54'\ 55''$.

From Table 3.2, *gatāṅka* = 89, *esyāṅka* = 93, difference = 4

Now, $\dfrac{4 \times 11^\circ\ 54'\ 55''}{15^\circ} + 89 = 92|10|39$

$\therefore$ *Mandaphala* = $\dfrac{92|10|39}{10} = 9^\circ\ 13'\ 04''$

The Mandaphala is negative since *MK* > 180°

Manda corrected Śani = Mean Śani + *Mandaphala*

$$= 11^R\ 0^\circ\ 36'\ 45'' + (-9^\circ\ 13'\ 04'')$$

$$= 10^R\ 21^\circ\ 23'\ 41''$$

(3) Second *Śīghra* correction :

Second SK = First SK – *Mandaphala*

$$= 63^\circ\, 36'\, 57'' - (-9^\circ\, 13'\, 04'') = 63^\circ\, 36'\, 57'' + 9^\circ\, 13'\, 04'' = 72^\circ\, 50'\, 01''$$

We have $\dfrac{72^\circ\, 50'\, 01''}{15^\circ} = 4 + \dfrac{12^\circ\, 50'\, 01''}{15^\circ}$; quotient = 4, remainder = $12^\circ\, 50'\, 01''$

From Table 3.1, *gatāṅka* = 48, *eṣyāṅka* = 54, difference = 6

Now, $\dfrac{6 \times 12^\circ\, 50'\, 01''}{15^\circ} + 48 = 53|8|0$

$\therefore$ *Śīghraphala* $= \dfrac{53|8|0}{10} = 5^\circ\ 18'\ 48''$

Hence, True Śani = $10^R\, 21^\circ\, 23'\, 41'' + 5^\circ\, 18'\, 48'' = 326^\circ\, 42'\, 29''$.

We shall now consider a modern example :

True positions of planets for August 11, 1998.

I. True position of Kuja :

For the given date 11th August 1998, we have

Ahargaṇa A = 2033 and *Cakra* C = 43

For Kuja, *Kṣepaka* $K = 10^R\ 7^\circ\ 8'$ and *Dhruvaka* $D = 1^R\ 25^\circ\ 32'$

$$\text{Mean } Kuja = \left\{ \left(\frac{10A}{19}\right)^\circ - \left(\frac{10A}{73}\right)' \right\} - C \times D + K$$

$$= \left\{ \left(\frac{10 \times 2033}{19} \right)^{\circ} - \left(\frac{10 \times 2033}{73} \right)' \right\} - 43 \times 55^{\circ}\, 32' + 10^{R}\; 7^{\circ}\, 8'$$

$$= \mathbf{64^{\circ}\, 33'\, 30''}$$

(1) First *Śīghra* correction :

Śīghrocca of Kuja = Mean Sun = $115^{\circ}\, 9'\, 59''$

Deśāntara corrected *Śīghrocca* of Kuja = $115^{\circ}\, 9'\, 42''$

Śīghrakendra = *Śīghrocca* – Mean Kuja

$$= 115^{\circ}\, 9'\, 42'' - 64^{\circ}\, 33'\, 30''$$

$$= 50^{\circ}\, 36'\, 12''$$

Bhuja of *Śīghrakendra* = $50^{\circ}\, 36'\, 12''$

Now, $\dfrac{Bhuja}{15^{\circ}} = \dfrac{50^{\circ}\, 36'\, 12''}{15^{\circ}} = 3 + \dfrac{5^{\circ}\, 36'\, 12''}{15^{\circ}}$

$\therefore$ quotient = 3, remainder = $5^{\circ}\, 36'\, 12''$

From Table 3.1, *gatāṅka* = 174, *eṣyāṅka* = 228 and difference = 54.

$$\therefore \frac{\text{Difference} \times \text{Remainder}}{15} + Gat\bar{a}\dot{n}ka$$

$$= \frac{54 \times 5^\circ 36' 12''}{15^\circ} + 174$$

$$= 194|10|19$$

$$\therefore \textit{Śīghraphala} = \frac{194|10|19}{10} = 19^\circ 25' 2''$$

$$\text{Half-}\textit{Śīghraphala} = \frac{19^\circ 25' 2''}{2} = 9^\circ 42' 31''$$

Half-*Śīghra* corrected Kuja = Mean Kuja + Half *Śīghraphala*

$$= 64^\circ 33' 30'' + 9^\circ 42' 31'' = 74^\circ 16' 01'.$$

(2) *Manda* correction :

Mandocca of Kuja = $4^R = 120^\circ$

Mandakendra = *Mandocca* – Half-*Śīghra* corrected Kuja

$$= 120^\circ - 74^\circ 16' 01'' = 45^\circ 43' 59''$$

Bhuja of *Mandakendra* = $45^\circ 43' 59''$

Now, $\frac{45^\circ 43' 59''}{15^\circ} = 3 + \frac{0^\circ 43' 59''}{15^\circ}$

$\therefore$ quotient = 3, remainder = $0^\circ 43' 59''$

From Table 3.2, *gatāṅka* = 85, *eṣyāṅka* = 109, difference = 24

$$\therefore\ Mandaphala = \frac{Gat\bar{a}\dot{n}ka + (\text{difference} \times \text{remainder})/\ 15}{10}$$

$$= \frac{85 + (24 \times 0^\circ\ 43'\ 59'')\ /\ 15^\circ}{10}$$

$$= 8^\circ\ 37'\ 2''$$

$\therefore$ *Manda* corrected Kuja = Mean Kuja + *Mandaphala*

$$= 64^\circ\ 33'\ 30'' + 8^\circ\ 37'\ 02''$$

$$= 73^\circ\ 10'\ 32''.$$

(3) Second *Śīghra* correction :

First *Śīghrakendra* = $50^\circ\ 36'\ 12''$

Mandaphala = $8^\circ\ 37'\ 2''$

$\therefore$ Second *Śīghrakendra* = $50^\circ\ 36'\ 12'' - 8^\circ\ 37'\ 2'' = 41^\circ\ 59'\ 10''$

Now, $\dfrac{41^\circ\ 59'\ 10''}{15^\circ} = 2 + \dfrac{11^\circ\ 59'\ 10''}{15^\circ}$

so that quotient = 2 and remainder = $11^\circ\ 59'\ 10''$

From Table 3.2, *gatāṅka* = 117, *eṣyāṅka* = 174, difference = 57

$$\acute{S}\bar{\imath}ghraphala = \frac{\left[\dfrac{(\text{difference} \times \text{remainder})}{15} + gat\bar{a}\dot{n}ka\right]}{10}$$

$$= \frac{\left[\frac{(57 \times 11^\circ 59' 10'')}{15^\circ} + 117\right]}{10}$$

$$= 16^\circ 15' 17''$$

$\therefore$ True Kuja = *Manda* corrected Kuja + *Śīghraphala*

$$= 73^\circ 10' 32'' + 16^\circ 15' 17''$$

$$= \mathbf{89^\circ 25' 49''}.$$

II. To find true position of Budha :

For the given date 11th Augutst 1998, we have

A = 2033 and C = 43

Mean Budha *Kendra* = $197^\circ 7' 47''$ (obtained in Chapter 1).

(1) First *Śīghra* correction :

Śīghrakendra of Budha SK = $197^\circ 7' 47''$

Mean Budha = Mean Sun = $115^\circ 9' 42''$

Since *SK > 180 °, we have*

Bhuja of *Śīghrakendra* = $197^\circ 7' 47'' - 180^\circ \;\; = 17^\circ 7' 47''$

Now, $\dfrac{17^\circ 7' 47''}{15^\circ} = 1 + \dfrac{2^\circ 7' 47''}{15^\circ}$

so that quotient = 1 and remainder = $2^\circ\,7'\,47''$

From Table 3.1, *gatāṅka* = 41, *eṣyāṅka* = 81, difference = 40

$$\therefore \textit{Śīghraphala} = \frac{\left[\dfrac{(\text{difference} \times \text{remainder})}{15} + \textit{gatāṅka}\right]}{10}$$

$$= \frac{\left[\dfrac{\left(40 \times 2^\circ\,7'\,47''\right)}{15^\circ} + 41\right]}{10}$$

$$= -4^\circ\,40'\,4''$$

Since *Śīghrakendra* = $197^\circ\,7'\,47'' > 180^\circ$, *Śīghraphala* is negative.

$\therefore$ Half-*Śīghraphala* = $-2^\circ\,20'\,2''$

Half-*Śīghra* corrected Budha = Mean Budha + Half-*Śīghraphala*

$$= 115^\circ\,9'\,42'' - 2^\circ\,20'\,2'' = 112^\circ\,49'\,40''.$$

***Manda* correction :**

Mandocca of Budha = $7^R = 210^\circ$

Mean Budha = Mean Sun = $115^\circ\,9'\,42''$

Half-*Śīghra* corrected Budha = $112^\circ\,49'\,40''$

Mandakendra = *Mandocca* – Half-*Śīghra* corrected Budha

$$= 210^\circ - 112^\circ 49' 40'' = 97^\circ 10' 20''$$

Bhuja of *Mandakendra* = $180^\circ - 97^\circ 10' 20''$

$$= 82^\circ 49' 40''$$

Now, $\dfrac{82^\circ 49' 40''}{15^\circ} = 5 + \dfrac{7^\circ 49' 40''}{15^\circ}$

so that quotient = 5 and remainder = $7^\circ 49' 40''$

From Table 3.2 *gatāṅka* = 35, *eṣyāṅka* = 36, difference = 1

$$\therefore \textit{Mandaphala} = \frac{\left[\dfrac{(\text{difference} \times \text{remainder})}{15} + \textit{gatāṅka}\right]}{10}$$

$$= \frac{\left[\dfrac{\left(1 \times 7^\circ 49' 40''\right)}{15^\circ} + 35\right]}{10} = 3^\circ 33' 8''$$

Manda corrected Budha = Mean Budha + *Mandaphala*

$$= 115^\circ 9' 42'' + 3^\circ 33' 8''$$

$$= 118^\circ 42' 50''.$$

(3) Second *Śīghra* correcion :

First *Śīghrakendra* = $197^\circ 7' 47''$

Mandaphala = $3^\circ\,33'\,8''$

$\therefore$ Second *Śīghrakendra* = $197^\circ\,7'\,47'' - 3^\circ\,33'\,8'' = 193^\circ\,34'\,39''$

Bhuja of *Śīghrakendra* = $193^\circ\,34'\,39'' - 180^\circ = 13^\circ\,34'\,39''$

Now, $\dfrac{13^\circ\,34'\,39''}{15^\circ} = 0 + \dfrac{13^\circ\,34'\,39''}{15^\circ}$

so that quotient = 0, remainder = $13^\circ\,34'\,39''$

From Table 3.1, *gatāṅka* = 0, *eṣyāṅka* = 41, difference = 41

$$\therefore\ \textit{Śīghraphala} = -\frac{\left[\dfrac{41\times 13^\circ\,34'\,39''}{15^\circ}+0\right]}{10} = -3^\circ\,42'\,40''$$

True Budha = *Manda* corrected Budha + *Śīghraphala*

$= 118^\circ\,42'\,50'' - 3^\circ\,42'\,40''$

$= 115^\circ\,0'\,10''$.

III. To find true position of Guru :

For the given date 11th August 1998,

A = 2033 and C = 43

Mean Guru = $330^\circ\,17'\,57''$

After *Dēśantara* correction Mean Guru = $330^\circ\,21'\,40''$

Mean Sun = $115^\circ\,9'\,42''$

(1) First *Śīghra* correction :

Śīghrakendra of Guru = *Śīghrocca* – Mean Guru

= Mean Sun – Mean Guru

$= 115^\circ\, 9'\, 42'' - 330^\circ\, 21'\, 40'' = 144^\circ\, 48'\, 2''$ (by adding 360°)

Bhuja = $144^\circ\, 48'\, 2''$

Now, $\dfrac{144^\circ\, 48'\, 2''}{15^\circ} = 9 + \dfrac{9^\circ\, 48'\, 2''}{15^\circ}$

so that quotient = 9 and remainder = $9^\circ\, 48'\, 2''$

From Table 3.1 *gatāṅka* = 89, *eṣyāṅka* = 66, difference = – 23

$$\therefore\ \textit{Śīghraphala} = \frac{\left[\dfrac{\left(-23 \times 9^\circ\, 48'\, 2''\right)}{15^\circ} + 89\right]}{10} = 7^\circ\, 23'\, 50''$$

Half-*Śīghraphala* = $3^\circ\, 41'\, 55''$

$\therefore$ Half-*Śīghra* corrected Guru = $330^\circ\, 21'\, 40'' + 3^\circ\, 41'\, 55'' = 334^\circ\, 3'\, 35''$

(2) *Manda* correction :

Mandocca of Guru = $6^R = 180^\circ$

Mandakendra = *Mandocca* – Half-*Śīghra* corrected Guru

$= 180^\circ - 334^\circ\, 3'\, 35''$

$= 205^\circ\ 56'\ 25''$ (by adding 360°)

'Bhuja' = $25^\circ\ 56'\ 25''$

Now, $\dfrac{25^\circ\ 56'\ 25''}{15^\circ} = 1 + 10^\circ\ 56'\ 25''/15^\circ$

so that quotient = 1 and remainder = $10^\circ\ 56'\ 25''$

From Table 3.2, *gatāṅka* = 14, *eṣyāṅka* = 27, difference = 13

$$\therefore Mandaphalam = \frac{\left[\left(\dfrac{13 \times 10^\circ\ 56'\ 25''}{15^\circ}\right) + 14\right]}{10} = -2^\circ\ 20'\ 53''$$

Mandaphala is negative since *Mandakendra* > 180°.

Manda corrected Guru = Mean Guru + *Mandaphala*

$= 330^\circ\ 21'\ 40'' - 2^\circ\ 20'\ 53'' = 328^\circ\ 0'\ 47''$

(3) Second *Śighra* correction :

Mandaphala = $-2^\circ\ 20'\ 53''$

First *Śīghrakendra* = $144^\circ\ 48'\ 2''$

Second *Śīghrakendra* = $144^\circ\ 48'\ 2'' + 2^\circ\ 20'\ 53''$ = $147^\circ\ 8'\ 55''$

Bhuja argument = $147^\circ\ 8'\ 55''$

Now, $\dfrac{147^\circ\ 8'\ 55''}{15^\circ} = 9 + \dfrac{12^\circ\ 8'\ 55''}{15^\circ}$

From Table 3.1, *gatāṅka* = 89, *eṣyāṅka* = 66 and difference $d = -23$

We have $\left(\frac{-23 \times 12^\circ\, 8'\, 55''}{15^\circ}\right) = -18|37|40$

$\therefore$ *Śīghrakendra* = $\frac{89 - 18|37|40}{10} = 7^\circ\, 2'\, 13''$

True Guru = Manda corrected Guru + *Śīghrakendra*

$= 328^\circ\, 0'\, 47'' + 7^\circ\, 2'\, 13'' = 335^\circ\, 3'\, 0''$

IV. To find true position of Śukra

For the given date 11th August 1998 we have

$A = 2033$ and $C = 43$

Mean *Śīghrakendra* of Śukra = $310^\circ\, 9'\, 46''$

Mean Śukra = Mean Sun = $115^\circ\, 9'\, 46''$

(1) First *Śīghra* correction :

Śīghrakendra of Śukra = $310^\circ\, 9'\, 46''$

Bhuja = $49^\circ\, 50'\, 14''$

Now, $\frac{49^\circ\, 50'\, 14''}{15^\circ} = 3 + \frac{4^\circ\, 50'\, 14''}{15^\circ}$

From Table 3.1, *gatāṅka* = 186, *eṣyāṅka* = 246 and difference = 60

Śīghraphala = $\frac{\left[\left(\frac{60 \times 4^\circ\, 50'\, 14''}{15^\circ}\right) + 186\right]}{10} = 20^\circ\, 32'\, 5''.$

Since $SK > 180^\circ$, the *Śīghraphala* is negative.

Half-*Śīghraphala* = $-10°16'3''$

Half-*Śīghra* corrected Śukra = Mean Śukra + Half-*Śīghraphala*

$$= 115°9'42'' - 10°16'3'' = 104°53'39''$$

***Manda* correction :**

Mandocca of Śukra = $3^R = 90°$

Mandakendra MK = *Mandocca* – Half-*Śīghra* corrected Śukra

$= 90° - 104°53'39'' = 345°6'21''$ (adding $360°$) > $180°$

Bhuja = $14°53'39''$

Now, $\dfrac{14°53'39''}{15°} = 0 + \dfrac{14°53'39''}{15°}$

From Table 3.2, *gatāṅka* = 0, *eṣyāṅka* = 06 and difference = 06

$$\therefore \textit{Mandaphala} = -\frac{\left[\dfrac{14°53'39''\times 06}{15°} + 0\right]}{10} = -0°35'44''$$

The *Mandaphala* is negative since $MK > 180°$.

Manda corrected Śukra = Mean Śukra – *Mandaphala* = $114°33'57''$

(3) Second *Śīghra* correction :

First *Śīghrakendra* = $310°9'46''$

Mandaphala = $-0°35'44''$

Second *Śīghrakendra* = $310°9'46'' + 0°35'44'' = 310°45'30''$

'Bhuja' = $49^\circ\ 14'\ 30''$

Now, $\dfrac{49^\circ\ 14'\ 30''}{15^\circ} = 3 + \dfrac{4^\circ\ 14'\ 30''}{15^\circ}$

From Table 3.1, *gatāṅka* = 186, *eṣyāṅka* = 246 and difference = 60

$$\therefore\ \textit{Śīghraphala} = -\frac{\left[\dfrac{60\times 4^\circ\ 14'\ 30''}{15^\circ}+186\right]}{10} = -20^\circ\ 17'\ 48^\circ$$

being negative since $SK > 180^\circ$.

True Śukra = *Manda* corrected Śukra + *Śīghraphala*

= $114^\circ\ 33'\ 57'' - 20^\circ\ 17'\ 48'' =$ **$94^\circ\ 16'\ 09''$**.

V. To find true position of Śani :

For the given date 11th August 1998 : $A = 2033$, $C = 43$

Mean Śani = $8^\circ\ 14'\ 2''$

Mean Sun = *Śīghrocca* of Śani = $115^\circ\ 9'\ 42''$

(1) First *Śīghra* correction :

Śīghrakendra of Śani = *Śīghrocca* – Mean Śani

= $115^\circ\ 9'\ 42'' - 8^\circ\ 14'\ 2'' = 106^\circ\ 55'\ 40''$

Bhuja argument = $106^\circ\ 55'\ 40''$

Now, $\dfrac{106^\circ\ 55'\ 40''}{15^\circ} = 7 + \dfrac{1^\circ\ 55'\ 40''}{15^\circ}$

From Table 3.1, *gatānka* = 57, *eṣyāṅka* = 53, difference = – 4

Now , *Śīghraphala* = $\dfrac{\left[\dfrac{-4 \times 1^\circ\ 55'\ 40''}{15} + 57\right]}{10} = 5^\circ\ 38'\ 55''$

Half-*Śīghraphala* = $2^\circ\ 49'\ 27''$

Half-*Śīghraphala* corrected Śani = $8^\circ\ 14'\ 2'' + 2^\circ\ 49'\ 27''\ =\ 11^\circ\ 03'\ 29''$

(2) *Manda* correction :

Mandocca of Śani = $8^R = 240^\circ$

Mandakendra = *Mandocca* – Half-*Śighra* corrected Śani

$= 240^\circ - 11^\circ\ 03'\ 29''\ =\ 228^\circ\ 56'\ 31''$

Bhuja argument = $48^\circ\ 56'\ 31''$

Now, $\dfrac{48^\circ\ 56'\ 31''}{15^\circ} = 3 + \dfrac{3^\circ\ 56'\ 31''}{15^\circ}$

From Table 3.2, *gatāṅka* = 60, *eṣyāṅka* = 77, difference = 17

$\therefore$ *Mandaphala* = $-\dfrac{\left[\dfrac{17 \times 3^\circ\ 56'\ 31''}{15^\circ} + 60\right]}{10} = -6^\circ\ 26'\ 48''$

Mandaphala = $-6^\circ\ 26'\ 48''$

being negative since $MK > 180^\circ$.

Manda corrected Śani = Mean Śani + *Mandaphalam*

$= 8^\circ\ 14'\ 2'' - 6^\circ\ 26'\ 48''\ =\ 1^\circ\ 47'\ 14''$.

(3) Second *Śīghra* correction :

First *Śīghrakendra* = $106^\circ 55' 40''$

Second *Śīghrakendra* = $106^\circ 55' 40'' + 6^\circ 26' 48'' = 113^\circ 22' 28''$

Now, $\dfrac{113^\circ 22' 28''}{15^\circ} = 7 + \dfrac{8^\circ 22' 28''}{15^\circ}$

From Table 3.1, *gatāṅka* = 57, *eṣyāṅka* = 53, difference = – 4

$$\therefore \textit{Śīghraphala} = \frac{\left[\left(\dfrac{-4 \times 8^\circ 22' 28''}{15^\circ}\right) + 57\right]}{10} = 5^\circ 28' 36''$$

True Śani : = *Manda* corrected Śani + *Śighraphala*

$= 1^\circ 47' 13'' + 5^\circ 28' 36'' = \mathbf{7^\circ 15' 49''}$.

Comparison of true positions of planets with the ephemeris values.

Date : August 11, 1998

Planets	According to *Grahalāghavam*	According to *Indian Ephemeris*
Ravi	113°51′ 33″	114°18′ 19″
Candra	331°55′ 27″	330°02′
Kuja	89°25′ 49″	89°48′ 40″
Budha	115°0′ 10″	119°37′ 01″
Guru	335°03′ 0″	333°18′ 07″
Śukra	94°16′ 09″	93°15′
Śani	7°15′ 49″	9°46′ 21″
Rāhu	44°21′ 03″	–

Note : The *Ayanāṃśa*, according to the *Grahalāghvam* for the given year *Śa.Śa.* 1920 is $(1920' - 444)' = 1476' = 24^\circ 36'$. According to the Indian Ephemeris, the *Ayanāmśa* = $23^\circ 50' 08''$. We find fairly a good agreement between the two sets of values for the positions of planets except in the case Śani and Budha.

True daily motions of the five star-planets

(*Gatispaṣṭīkaraṇam*)

Ślōka 11 : This *śloka* explains the method of obtaining *Manda* corrected motions of Śani, Kuja Guru, Budha and Śukra.

(i) Divide the difference of *Mandāṅkas* of Śani, Kuja and Guru by 75, 5 and 30 respectively.

(ii) Multiply the difference of *Mandāṅkās* of Budha and Śukra by 2 and divide by 5 respectively.

(iii) Step (i) and step (ii) give *Manda gatiphala* of respective planets which will be in minutes of arc *(kalās).*

(iv) Add (or subtract) the *Mandagatiphala* to mean motion of planets to get *Manda* corrected motion.

Note : If the *Mandakendra* of a planet is within 6 *Rāśis* from *Karka* (i.e., if the planet is in II or III quadrant) the *gatiphala* is additive.

If the *Mandakendra* of the planet is within 6 *Rāśis* from *Makara*, (i.e., if the planet is in IV or I quadrant) then the *gatiphala* is subtractive.

Ślōka **12** : The method of obtaining true daily motions of planets is explained as follows.

1. True daily motion of Kuja :

(i) Obtain the *Manda*-corrected motion as explained in the previous *śloka.*

(ii) Take the difference between *Śīghrāṅkas* which are obtained in finding the second *Śīghraphala.*

(iii) Divide the difference obtained in step (ii) by 5. The result will be in minutes of arc *(kalās)*

(iv) Add (or subtract) the above *kalās* to *Manda* corrected motion. This gives the true daily motion of the planet.

Note : If the first *Śīghrāṅka* (i.e., elapsed *Śīghrāṅka*) is less than the second *Śīghrāṅka* (i.e., *Śīghrāṅka* to be covered) then add the result of step (iii) to the *Manda* corrected planet. On the otherhand, if the first *Śīghrāṅka* is greater than the second then subtract the result of step (iii) from the *Manda* corrected planet.

The same rule holds in the case of other planets also.

Example : In the case of Kuja, we have

(i) The difference between the *Mandāṅkas* = 28 (see the first example under *Śloka* 9)

(ii) *gatiphalam* = $\frac{28}{5} = 5' \, 36''$

(iii) Since *Mandakendra* is within 6 *Rāśis* from *Karka,* the *gatiphalam* is additive.

$\therefore$ *Manda* corrected motion of *Kuja* = Mean motion of Kuja + *gatiphalam*

$= 31' \, 36'' + 5' \, 36'' \;\; = 37' \, 12''$

(iv) The difference between the *Śīghrāṅkas* = 40 since the elapsed *Śīghrāṅka* = 325 and the *Śīghrāṅka* to be covered = 365.

(v) Since the elapsed *Śīghrāṅka* is less than the *Śīghraṅka* to be covered,

add $\frac{40}{5} = 8' \, 0''$ to the *Manda* corrected planet.

$\therefore$ True motion of Kuja = *Manda* corrected motion of Kuja $+ 8' \, 0''$

$= 37' \, 12'' + 8' \, 0'' \;\; = 45' \, 12''$.

2. True daily motion of Budha

(i) Obtain the *Manda* corrected Budha's motion as explained earlier.

(ii) Consider the difference between the elapsed *Śīghrāṅka* and the *Śīghrāṅka* to be covered, which are obtained in finding the second *Śīghraphala.*

(iii) Divide the difference obtained in step (ii) by 5; the result will be in *kalās*, (minutes of arc).

(iv) Add the result of step (iii) to the difference obtained in step (ii).

(v) Add (or subtract as the case may be) the result of step (iv) to the *Manda* corrected motion of Budha.

Example : The difference of *mandāṅkas* = 12

$$\therefore \textit{gatiphalam} = \frac{12\times 2}{5} = 4'\,48''$$

The *Manda* corrected motion = Mean motion + *gatiphalam*

$= 59'\,8'' + 4'\,48'' \;=\; 63'\,56''$

Difference between *Śīghrāṅkas* = 33

$$\therefore\ \textit{ghatiphalam} = \frac{33}{5} = 6'\,36''$$

Now, the difference between *Śighrānkas* + $6'\,36'' = 33' + 6'\,36'' \;=\; 39'\,36''$

$\therefore$ True motion of Budha = *manda* corrected motion $+39'\,36''$

$= 63'\,56'' + 39'\,36'' \;=\; 103'\,32''$

3. True Motion of Guru :

(i) Obtain the *Manda* corrected motion of Guru as explained earlier.

(ii) Obtain the difference of *Śīghrāṅkas* which are obtained in finding the second *Śīghraphala.*

(iii) Divide the above difference by 3. The result will be in *kalās.*

(iv) Add (or subtract) the above result to the *manda* corrected motion of Guru.

Example :

The difference of the *Mandāṅkas* = 9

gatiphalam = $\frac{9}{30} = 0'18''$

The *Manda* corrected motion = Mean motion – *gatiphalam*

$= 5' - 0'18'' = 4'42''$

Now, the difference between *Śīghrāṅkas* = 2 and

gatiphalam = $\frac{2}{3} = 0'40''$

True motion of Guru = The *Manda* corrected motion + $0'40''$

$= 4'42'' + 0'40'' = 5'22''$

4. True motion of Śukra :

(i) Obtain the *Manda* corrected motion of Śukra as explained in the previous *śloka.*

(ii) Obtain the difference between the *Śīghrāṅkas* of the second *Śīghraphala.*

(iii) Divide the above difference by 4. The result will be in *kalās.*

(iv) Add (or subtract) the result of step (iii) to the *Manda* corrected motion of Śukra.

Example : The difference between the *Mandāṅkas* = 2

$\therefore$ *gatiphalam* = $2 \times \frac{2}{5} = 0'48''$

The *Manda* corrected motion of Śukra = Mean motion of Śukra – *gatiphalam*

$$= 59'08'' - 0'48'' = 58'20''.$$

Difference of the *Śīghrāṅkas* = 48

$\therefore$ *gatiphalam* = $\frac{48}{4} = 12'0''$

True motion of Śukra = *Manda* corrected motion of Śukra + $12'0''$

$$= 58'20'' + 12'0'' = 70'20''$$

5. True daily motion of Śani :

(i) Obtain the *Manda*-corrected motion of Śani as explained earlier.

(ii) Obtain the difference of the *Śīghrāṅkas* of the second *Śīghraphala*

(iii) Multiply the above difference by 2 and divide it by 5. The result will be in *kalās*.

(iv) Add (or subtract) the above *kalās* to the *Manda*-corrected motion of Śani. This gives the true motion of Śani.

Example : The difference between the *Mandāṅkās* = 4

$\therefore$ *gatiphalam* = $\frac{4}{75} = 0'03''$

Now, the *Manda* corrected motion = Mean motion + *gatiphalam*

$$= 2' + 0'03'' = 2'03''$$

The difference between the *Śīghrāṅkas* = 6

Now, *ghatiphalam* = $6 \times \frac{2}{5} = 2'24''$

$\therefore$ True daily motion of Śani = *Manda* corrected motion + $2'24''$

$$= 2'03'' + 2'24'' = 4'27''$$

***Śloka* 13** : In the case Kuja and Śukra, due to large differences in their *Śīghrāṅkas* an additional correction, in each case, to the *Śīghraphala* is given.

In the process of determining the second *Śīghra* correction, when the *Śīghrakendra* is divided by $15°$, let the quotient be Q and the remainder R. Now, between R and $15-R$, take the lesser one and call it R'. Divide R' by 5 in the case of Kuja and by 3 in the case of Śukra. The result in degrees etc. should be added to or subtracted from the *Śīghra* corrected planet according as the *Śīghraphala* is additive or subtractive. In the case of the other three *tarāgrahas* viz. Budha, Guru and Śani, this second difference is negligible and hence omitted.

Example:

Considering the example worked out earlier for Kuja, we have

Śīghrakendra = $91° 4' 57''$.

Between $(1° 4' 57'')$ and $15° - (1° 4' 57'')$ i.e., $13° 55' 03''$, the former is less.

Dividing the lesser value by 5, we get $1° 4' 57''/5 = 12' 59''$. Since the *Śīghraphala* is additive, we add $12' 59''$ to the *Śīghra* corrected Kuja to get:

the true Kuja = $336° 00' 28'' + 12' 59'' = 336° 13' 27''$.

In the case of Śukra, the *Śīghrakendra* = $94° 29' 52''$. Dividing by $15°$ the quotient is 6 and the remainder is $4° 29' 52''$. Between this value and its difference from $15°$ viz., $10° 30' 08''$, the former is less. Dividing the lesser

value by 3, we get $4^\circ 29' 52''/3 = 1^\circ 29' 57''$. Since the *Śīghraphala* is additive, by adding $1^\circ 29' 57''$ to the *Śīghra* corrected Śukra, we get corrected true Śukra $72^\circ 15' 46'' + 1^\circ 29' 57'' = 73^\circ 45' 43''$.

***Śloka* 14** : While finding the final *Śīghrāṅka* of Kuja, Budha and Śukra, the remainders obtained must be multiplied by 10 and then divided respectively by 7, 7 and 3; the result be added respectively to 35, 97 and 53. This gives the corrected *gatiphala* (of Kuja, Budha and Śukra). These must be accepted and not the one obtained earlier.

Example : Suppose the second *Śīghrāṅka of* Kuja is 11 and the remainder, $11^\circ 50' 0''$. Now, multiplying the remainder by 10 and dividing by 7, we get $11|50 \times \frac{10}{7} = 16'54''17'''$ as the *Śīghra gatiphala*. This is subtractive since the *Śīghra gatāṅka* and the *eṣyāṅka* are respectively 249 and 0 corresponding to the quotients 11 and 12 and hence decreasing. Therefore, subtracting $51'54''17'''$ from the already obtained *Manda spaṣṭagati* of $25'43''$, we get the final true daily motion of Kuja as $25'43'' - 51'54''17''' = -26'11''17'''$ (*retrograde* since negative).

***Śloka* 15** : Retrograde motion of planets is explained. The *Śīghrakendras* of the planets for (the commencement of) retrograde motion (*vakragati*) are $163^\circ, 145^\circ, 125^\circ, 167^\circ, 113^\circ$. The retrogression continues till the *Śīghrakendras* become 360° *minus* the above values (i.e, 197°, 215°, 235°, 193°, 247°) respectively for Kuja, Budha, Guru, Śukra and Śani.

Retrograde Motion of Star-Planets

The star-planets move from west to east, relative to the fixed stars, as seen from the earth, due to their natural motion. However, during cer-

tain periods each of these planets appears to move backwards, i.e., from east to west. Their celestial longitudes keep on decreasing instead of increasing, day by day, for some time. This apparent backward motion is called *vakragati* (retrograde motion).

The phenomenon of retrograde motion is caused by the difference in the angular velocities of the earth and the planet, i.e, the relative velocity. This phenomenon is demonstrated in Fig. 3.1.

In Fig. 3.1 the motion of Mars (Kuja) relative to the earth is shown in the heliocentric model. The earth's linear speed is 18.5 miles per second while that of Mars is 3.5 miles less, i.e, 15 miles per second. As the earth overtakes Mars, the latter appears to move backwards, when seen from the earth. The direct motion of Mars eastward is shown at positions 1, 2 and 3, the retrograde at 4 and 5 westward and again direct motion eastward at 6 and 7.

The rule for determining the retrograde motion of a planet is given in the *Sūryasiddhānta* as follows :

The retrograde motion (*vakragati*) of the different star-planets commences when the *Śīghrakendra* (i.e., *Śīghra* anomaly), in the fourth process of determining true positions, is as follows :

Kuja 164°, Budha 144°, Guru 130°, Śukra 163°, Śani 115°

That is, the retrograde motion of Kuja, for example, commences when its

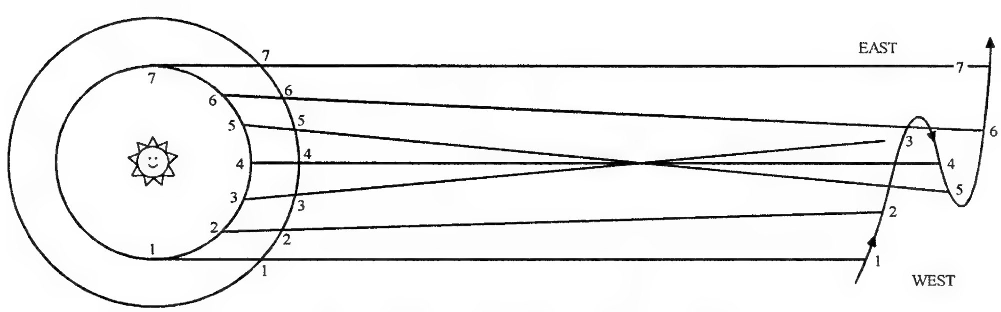

Fig. 3.1 Retrograde motion of Kuja

The point at which the motion of a planet changes from direct to retrograde is called a "*stationary point*". The planet remains retrograde for some days and then, again, its motion changes from retrograde to direct. This point of change is the second stationary point. At both the stationary points the planet has no apparent motion (i.e., the relative velocity is zero).

Bhāskara II (b. 1114 A.D.) in his *Siddhānta Śiromaṇi* (*Spaṣṭādhyāya*) mentions that at the maximal point the (angular) velocity of the planet vanishes :

यत्र ग्रहस्य परमं फलं तत्रैवगतिफलाभावेन भवितव्यम् ।

yatra grahasya paramaṃ phalaṃ tatraivagati phalābhāvena bhavitavyam /

Rationale for the Stationary Point

In Fig. 3.2 let M be the mean planet, P be the true planet on the epicycle of radius p, E be the earth and S the Sun, If n is the mean daily motion of the Sun, let t be the number of days since the Sun S was at the first point of *Meṣa*, $P\hat{M}K = \theta$ and $P\hat{E}M = E$, then the celestial longitude L of the planet is given by $L = nt - \theta + E$ where nt is the longitude of the Sun. Therefore,

$$\frac{dL}{dt} = n - \frac{d\theta}{dt} + \frac{dE}{dt} \qquad \dots (1)$$

Let $PM = p$ and $EM = r$, where the radii p and r are constants. In Fig. 3.2, we have $MA = p\cos\theta$ and $PA = p\sin\theta$. Therefore,

$EA = EM + MA = r + p\cos\theta$ and hence

$$\tan E = \frac{PA}{EA} = \frac{p\sin\theta}{(r + p\cos\theta)} \quad \text{so that} \quad E = \tan^{-1}\left[\frac{p\sin\theta}{(r + p\cos\theta)}\right]$$

Differentiating this expression with respect to t we get

$$\frac{dE}{dt} = \frac{\left(\frac{d\theta}{dt}\right)\left[r^2 + rp\cos\theta\right]}{\left[r^2 + p^2 + 2rp\cos\theta\right]} \qquad \text{... (2)}$$

Substituting (2) in (1), we get

$$\frac{dL}{dt} = n - \left(\frac{d\theta}{dt}\right)\left[\frac{\left(r^2 + rp\cos\theta\right)}{\left(r^2 + p^2 + 2rp\cos\theta\right)}\right] \qquad \text{... (3)}$$

If n is the mean daily motion of the Sun and n' is that of the planet and α is a suitable constant, then

$$\theta = (n - n')(t + \alpha)$$

so that $\frac{d\theta}{dt} = (n - n')$ .... (4)

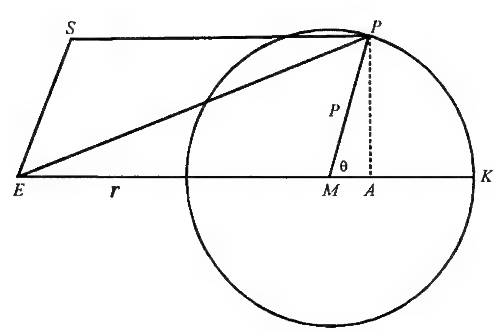

Fig.3.2. Stationary points

Substituting (4) in (3), we get

$$\frac{dL}{dt} = \frac{\left[np^2 + n'r^2 + rp(n + n')\cos\theta\right]}{\left[r^2 + p^2 + 2rp\cos\theta\right]}$$

At the stationary point where the retrograde motion begins, $\frac{dL}{dt} = 0$.

Therefore, $np^2 + n'r^2 + rp(n + n')\cos\theta = 0$

so that $\cos\theta = -\frac{(np^2 + n'r^2)}{pr(n + n')}$

For example, in the case of Kuja, considering the mean values, we have $n = 0°.98560265$, $n' = 0°.5240193$, $p = 233°.5$, $r = 360°$. Here, p and r are taken as peripheries of the planet's *Śīghra* epicycle and of the mean orbit, which are proportional to their radii. Substituting these values, we arrive at

$$\cos\theta = -\frac{[0.98560265\ (233.5)^2 + 0.5240193\ (360)^2]}{[(233.5)(360)(1.5096219)]}$$

$$= \frac{-[53737.271 + 67912.901]}{[126898.82]} = \frac{-12650.17}{126898.82} = -0.9586391$$

Therefore,

$$\theta = 180° - \cos^{-1}(0.9586391) = 163°.4636$$

The *Sūryasiddhānta* has taken this value as $164°$ while *GL* takes it as $163°$. The other stationary point is given by $360° - \theta$, noting that

$$\cos\theta = \cos(360^\circ - \theta)$$

In the above example, since $\theta = 164^\circ$ according to the *Sūryasiddhānta*, the second stationary point is $360^\circ - 164^\circ = 196^\circ$. This means that Kuja will be retrograde during the peirod when its *Śīghrakendra* (or *Śīghra* anomaly) lies between 164° and 196°. Similarly, the corresponding limits for other planets can be calculated.

Remark : According to modern astronomy, the stationary value of the angle θ is given by

$$\cos\theta = \frac{-\left[a^{1/2}\, b^{1/2}\right]}{\left[a - a^{1/2}\, b^{1/2} + b\right]}$$

where a is the mean distance of the planet from the Sun and b is the mean distance of the earth from the Sun. Now, taking b as one astronomical unit (a.u.) we have

$$\cos\theta = \frac{-\left[a^{1/2}\right]}{\left[a - a^{1/2} + 1\right]}$$

where a is the mean distance of the planet from the Sun, in astronomical unit (a.u.).

Note : 1 astronomical unit (a.u.) = Earth's mean distance from the Sun.

The stationary points θ, given in Table 3.5, are those at which the re-

spective planets change their motion from direct to retrograde, i.e., the beginning of the retrograde motion (*vakrārambha*). The other stationary points, where the retrograde motion ends (*vakratyāga*), are given by $(360° - \theta)$.

It is noteworthy that Bhāskara II gives the correct value $\theta = 167°$ for Śukra in his *Karaṇa kutūhalam.*

For comparison, we tabulate the critical values of the *Śīghrakendras* for the retrograde motion of the planets according to the different texts :

Table 3.5 *Śīghrakendras* for retrograde motion

Planet	*Sūrya-Siddhānta*	Brahma-gupta	Bhāskara II and Lalla	*Graha-lāghavam*	Modern
Kuja	164°	164°	163°	163°	163°.215
Budha	144°	146°	145°	145°	144°.427
Guru	130°	125°	125°	125°	125°.565
Śukra	163°	165°	165°	167°	167.005
Śani	115°	116°	113°	113°	114°.466

Note : Brahmagupta has given the stationary value θ for Guru as $125°$ in his *Brahmasphuṭa siddhānta* and as $130°$ in his *Khaṇḍakhādyaka.*

***Śloka* 16** : This *śloka* tells the *Śīghrakendra* of *udayāsta* (rising and setting) of Kuja, Guru and Śani.

When the *Śīghrakendra* of Kuja, Guru and Śani becomes $28°$, $14°$ and $17°$ respectively, these planets rise in the east. Subtracting the above *Śīghrakendra* values from $360°$ we get the *Śīghrakendra* of setting of these planets in the west respectively. That is Kuja, Guru and Śani, set in the west when their *Śīghrakendras* become $332°$, $346°$ and $343°$ respectively.

***Śloka* 17** : This *śloka* gives the *Śīghrakendra* of *udayāsta* of Budha and Śukra.
When the *Śīghrakendra* of Budha and Śukra become $50°$ and $24°$ respectively they rise in the west and when their *Śīghrakendras* become $155°$ and $177°$ they set in the west.

Similarly, when *Śīghrakendras* for Budha and Śukra become respectively $205°$ and $283°$ they *rise in the east* and for $310°$ and $336°$ they *set in the east.*

***Śloka* 18** : The *śloka* explains the number of days for the commencement of or the elapsed or balance of the phenomena of retrogression, rising and setting.

(1) Find the *Śīghrakendra (SK)* of the planet for the given day.

(2) Find the difference between the above *Śīghrakendra* and the presribed *Śīghrakendra* of retrograde motion or of rising or setting of the concerned as desired.

(3) This difference is multiplied by 2 for Kūja, divided by 3 for Budha, divided by 9 and added to itself (the difference) for Guru, multiplied by 10 and divided by 6 for Śukra and the difference divided by 1 (i.e., the difference itself) for Śani gives the *gata* or *eṣya* (elapsed or balance) days of retrogression or rising or setting as the case many be.

(ii) If the current *SK* is greater than the prescribed *SK* for the particular phenomenon, then the planet will be undergoing the said phenonemon and the number of days elapsed since the commencement of the same is as explained above.

***Śloka* 19** : Now, for Budha and Śukra the phenomena of retrogression, rising and setting and the number of days of the same are explained.

Thirty two days after the setting in the east Budha rises in the west, 32 days later Budha becomes retrograde, *vakrī*, 3 days after that sets in the west, 16 days later Budha rises in the east and becomes direct (*mārgī*) and 32 days after this the planet sets in the east.

Similarly, Śukra, 2 months after setting in the east rises in the west, 8 months later becomes retrograde and $\frac{3}{4}$ month (i.e., about 22 ½ days) after this sets in the west; after this $\frac{1}{4}$ month (7 ½ days) later Śukra rises in the east. Further, $\frac{3}{4}$ month (22 ½ days) later becomes direct and 9 months after this, Śukra sets in the east. Thus, the cycles for Budha and Śukra repeat.

***Śloka* 20** : Now, rising, retrogression and setting days for Kuja, Guru and Śani are explained.

Kuja rises (in the east) four months after setting (in the west). The planet becomes retrograde ten months after rising. Kuja resumes direct motion two months later and sets ten months after that.

Guru rises one month after his setting. He becomes retrograde four-and-a-quarter months later. After four months of becoming retrograde, Guru becomes direct. Finally, he sets four-and-a-quarter months later.

Śani rises, becomes retrograde, resumes direct motion and sets respectively after $\frac{5}{4}$, $\frac{7}{2}$, $\frac{9}{2}$ and $\frac{7}{2}$ months successively (i.e. rises $\frac{5}{4}$ months after setting etc.).

CHAPTER 4

TRIPRAŚNĀDHIKĀRA

(Three Problems of Direction, Place and Time)

This chapter deals with issues connected with direction, place and time (*dik*, *deśa* and *kāla*). The shadow of the gnomon (*śaṅku*) occupies an important role in determining the altitude of the Sun, the direction, the time, Sun's declination and the latitude of a place. In this chapter, besides these, the ascending point of the ecliptic at the eastern horizon (*Lagna*, Ascendant), the rising and setting of the Sun etc. are discussed.

***Śloka* 1** : The durations of the rising of *Meṣa*, *Vṛṣabha* and *Mithuna* at *Laṅkā* are respectively 278, 299 and 323 in *vighaṭīs*. These figures written in the reverse order are the durations of risings of the next three *rāśis*. That is, the durations of risings of *Karkaṭaka*, *Simha* and *Kanyā* are respectively 323, 299 and 278.

The durations of the rising (*udayamāna*) of *Meṣa*, *Vṛṣabha* and *Mithuna*, diminished by the *cara khaṇḍas* are the durations of the risings of these three *rāśis* at one's place [see Ch. 2, *Śl.* 5].

The durations of the risings of *Karkaṭaka*, *Simha* and *Kanyā* increased by the *carakhaṇḍas* are the durations of the risings of these three *rāśis* at one's place.

The durations of risings of these six *rāśis*, that is from *Meṣa* to *Kanyā* written in the reverse order give the durations of the risings of the six *rāśis* from *Tulā* to *Mīna* [see Table 4.1].

Table 4.1 *Udayamānas (vig.)* of *Rāśis* at *Laṅkā*

Rāśis	Durations of risings
Meṣa	278
Vṛṣabha	299
Mithuna	323
Karkaṭaka	323
Simha	299
Kanyā	278
Tulā	278
Vṛścika	299
Dhanu	323
Makara	323
Kumbha	299
Mīna	278

The sum of the durations of the risings (*udayamānas*) of the six *rāśis* at a place is 1800 *palas* (*vig.*)

The sum of the durations of the risings of all 12 *rāśis* is 3600 *palas* [60 *palas* = 1 *ghaṭī*].

The durations of the risings of rāśis for Kāśī

The *palabhā* of *Kāśī* = 5|45 *aṅgulas.*

Carakhaṇḍas of *Kāśi* are 57, 46, 19 *palas.*

The durations of the risings of *rāśis* are given in Table 4.2 :

Table 4.2 ***Udayamānas*** **of** ***Rāśis*** **at Kāśī**

Meṣa	278 - 57 = 221	*Mīna*
Vṛṣabha	299 - 46 = 253	*Kumbha*
Mithuna	323 - 19 = 304	*Makara*
Karkaṭaka	323 + 19 = 342	*Dhanu*
Simha	299 + 46 = 345	*Vṛścika*
Kanyā	278 + 57 = 335	*Tulā*

Note : According to the *Sūryasiddhānta* the durations of the risings of *rāśis* (starting from *Meṣa*) are respectively 1670, 1795 and 1935 *asus* where 6 *asus* = 1 *pala* (*vighaṭī* or *vināḍī*)

Therefore, 1670 *asus* = 278.33 *palas*

1795 *asus* = 299.17 *palas*

1935 *asus* = 322.5 *palas*

Now, 1670 + 1795 + 1935 = 5400 *asus* = 900 *palas*

According to the *Grahalāghavam*, we have 278 + 299 + 323 = 900 *palas*.

Ślokas **2 and 3** : These *ślokas* explain the method of finding *lagna* (ascendant) at a given time. It is as follows :

(i) Determine the *sāyana* Ravi at the given time.

(ii) Find the *amśas* to be covered (*bhogyāmśa*) by dividing the true position (in degrees) of the Sun by 30 and subtracting the remainder from 30^0.

(iii) Multiply the above remainder (degrees) by the *udayamāna* (duration of rising) of that particular *rāśi* and divide the product by 30. The result gives the *bhogya kāla* (the duration to be covered) in *palas* (*vighaṭīs*) of that *lagna*.

(iv) Express the given time (after sunrise) in *palas* and subtract the *bhogya kāla* (in *palas*) from it.

(v) Subtract the total duration (in *palas*) of the *śuddha rāśis* (i.e. already completed *lagna rāśis*) from the result of item (iv).

(vi) *Bhuktāṃśa* (ellapsed portion) of *lagna*

$$= \frac{\text{Remainder from (v)} \times 30^\circ}{\textit{Udayamāna} \text{ of the current } \textit{lagna rāśi}}$$

(vii) Adding the above *bhuktāṃśas* to the *śuddha rāśis* (i.e., completed *rāśis*)

we get *sāyana spaṣṭa lagna*. Subtract the *ayanāṃśa* to get the *nirayaṇa lagna*.

Example : Given time (*Iṣṭakāla*) = $10^{gh}\ 30^{vig}$ from sunrise at *Kāśī*

Ayanāṃśa = $18^\circ\ 0'$

(i) *Sāyana* Sun at the given time = $54^\circ\ 2'\ 40''$

(ii) Dividing by 30, $\dfrac{54^\circ\ 2'\ 40''}{30^\circ} = 1 + \dfrac{24^\circ\ 2'\ 40''}{30^\circ}$

i.e., quotient = 1 and remainder = $24^\circ\ 2'\ 40''$

The *amśas* to be covered = $30^\circ - 24^\circ\ 2'\ 40'' = 5^\circ\ 57'\ 20''$

in the 2nd *rāśi* i.e., *Vṛṣabha*.

This implies that the Sun is in the *Vṛṣabha rāśi*, with remainder

$5^\circ\ 57'\ 20''$.

At *Kāśī*, the duration of rising of *Vṛṣabha rāśi* = 253 *palas*.

$$\therefore \quad \textit{Bhogyakāla} = \frac{5^\circ\ 57'\ 20'' \times 253}{30^\circ} \approx 50.225 \ \textit{palas} \ \approx 50 \ \textit{palas}$$

Now, the given time = $10^{gh}\ 30^{vig}$ = 630 *palas* (after sunrise).

(iii) The given time – *bhogyakāla* = 630 – 50 = 580 *palas*.

(iv) The duration of the rising *udayamāna* of *Mithuna* = 304 *palas*.

Now, 580 – 304 = 276 *palas*

The duration of the rising of *Karkaṭaka* = 342 *palas*.

which cannot be subtracted from 276 (and hence the *aśuddha rāśi*).

We have $\dfrac{276 \times 30^\circ}{342} = \dfrac{8280^\circ}{342} = 24^\circ\ 12'\ 37''$

The number of elapsed *rāśis* from *Meśa* = 3

$$\therefore \quad \textit{Sāyana lagna} = 3^R + 24^\circ\ 12'\ 37'' = \mathbf{3^R\ 24^\circ\ 12'\ 37''}$$

and hence *nirayaṇa lagna* = *Sāyana lagna* – *Ayanāṃśa*

$$= 3^R\ 24^\circ\ 12'\ 37'' - 18^\circ\ 10' = \mathbf{3^R\ 6^\circ\ 2'\ 37''}$$

i.e., *Karkaṭaka* $6^\circ\ 2'\ 37''$.

***Śloka* 4** : This *śloka* explains the method of finding the *lagna* when the time to be covered is greater than the given time (i.e., if *bhogyakāla* > *iṣṭakāla*) and also gives the method of finding the time from *lagna*. The procedure is as follows.

(i) Find the true longitude of the (*sāyana*) Sun at the given time.

(ii) Find the time to be covered (*bhogyakāla*) (as explained in *Ślokas* 2 & 3).

(iii) If the time to be covered is greater than the given time, multiply the given time by 30 and divide by the duration of the rising of the *rāśi* in which the *sāyana* Sun lies.

(iv) Add the quotient obtained in step (iii) to the true (*sāyana*) longitude of the Sun. This gives the *sāyana lagna* at the given time.

Example : The given time = $0^{gh}\ 40^{vg}$. At this instant, we have

The *sāyana* Sun = $1^R\ 24°\ 02'\ 40''$

Now, $$\frac{54°\ 02'\ 40''}{30} = 1 + \frac{24°\ 02'\ 40''}{30°}$$

Here, the quotient = 1 and the remainder = $24°\ 02'\ 40''$

The *amśas* to be covered = $30° - 24°\ 02'\ 40'' = 5°\ 57'\ 20''$

This implies that the Sun is in the *Vṛṣabha rāśi* with remainder $5°\ 57'\ 40''$.

The duration of rising of the *Vṛṣabha rāśi* is 253 *palas*.

Now, $$\frac{5°\ 57'\ 40'' \times 253}{30°} = 50.225185\ \textit{palas} \approx 50\ \textit{palas}$$

i.e., *Bhogyakāla* = 50 *palas.*

The given time (*Iṣṭakāla*) = 40 *palas.*

Since *Bhogyakāla* > *Iṣṭakāla,* multiplying the given time by 30 and dividing by 253 we get

$$\frac{40 \times 30^\circ}{253} = 4^\circ\ 44'\ 35''$$

Sāyana Ravi is in *Vṛṣabha rāśi* $5^\circ\ 43'\ 15''$

$\therefore$ *Sāyana lagna* = *Sāyana* Ravi + $4^\circ\ 44'\ 35''$

$$= 1^R\ 5^\circ\ 43'\ 15'' + 4^\circ\ 44'\ 35'' = 1^R\ 10^\circ\ 27'\ 50''$$

$\therefore$ *Nirayaṇa lagna* = $40^\circ\ 27'\ 50'' - 18^\circ\ 10' = 22^\circ\ 17'\ 50''$ (i.e., in *Meṣa*)

Finding the time from *lagna* :

(i) Find the *bhogyāṃśa* of the *sāyana* Ravi.

(ii) Find the covered portion of the *lagna* (i.e., *bhuktakāla* of the *lagna*).

(iii) Take the sum of the results of step (i) and step (ii).

(iv) Consider the duration of rising of the *rāśi* that lies between the *sāyana* Ravi and the *sāyana lagna*. Add this to the sum obtained in step (iii). This gives the required time in *palas*. Divide it by 60 to convert the time into *ghaṭīs* etc.

Example : *Nirayaṇa lagna* = $3^R\ 6^\circ\ 2'\ 37''$

Sāyana lagna = $3^R\ 24^\circ\ 12'\ 37''$

i.e., *Sāyana lagna* is in *Karka rāśi* with elapsed portion = $24^\circ\ 12'\ 37''$.

The duration of rising (*udayamāna*) of *Karka rāśi* = 342 *vig.* at *Kāśī.*

Now, the elapsed time = $\dfrac{24^\circ\, 12'\, 37'' \times 342}{30^\circ}$ *palas* = 276 *palas.*

Similarly the *bhogyakāla* of Ravi = 50 *palas.*

Now, $276 + 50 = 326$ *palas.*

We note that the *sāyana lagna* is in *Karka rāśi* and the *sāyana* Ravi is in *Vṛṣabha rāśi.* We have *Mithuna rāśi* in between these two.

The durations of the rising of *Mithuna* = 304 *palas.*

Now, 326 + 304 = 630 *palas* i.e., $10^{gh}\ 30^{vg}$

i.e., the required time at the given *lagna* = $10^{gh}\, 30^{vg}$ from the sunrise.

***Śloka* 5** : The method of finding the time from *lagna* when the *śāyana* Ravi and *sāyana lagna* are in the same *rāśi,* is explained as follows :

1. When the Sun and *lagna* are in the same *rāśi*, consider the difference between the Sun and the *lagna.*

2. Multiply the above difference by the duration of rising of the *rāśi* in which both the Sun and the *lagna* are present.

3. Divide the product obtained in step (2) by 30. This gives the time in *palas* at the given *lagna.* Divide it by 60 to convert it into *ghaṭīs.*

Note : If *lagna* < the Sun, then subtract from 60 the time obtained in step (3).

Example 1 : *Sāyana lagna* = $1^R\ 28^\circ\ 37'\ 50''$

Sāyana Ravi = $1^R\ 23^\circ\ 53'\ 15''$

(i) *Lagna* – Ravi = $4^\circ\ 44'\ 35''$

We note that Ravi and *lagna* both are in *Vṛṣabha rāśi.*

The duration of rising of *Vṛṣabha* = 253 *palas.*

(ii) Now, $\dfrac{4^\circ\ 44'\ 35'' \times 253}{30^\circ}$ *palas* ≈ 40 *palas.*

$\therefore$ The time = 40 *palas* = $0^{gh}\ 40^{vig}$

Example 2 : When *Lagna* < Sun

The given time after sunrise = 59 *ghaṭīs.*

True longitude of Ravi at this instant = $1^R\, 6^\circ\, 39'\, 07''$.

Adding 6 *rāśis* and the *ayanāṃśa* we get

$$1^R\, 6^\circ\, 39'\, 07'' + 6^R + 18^\circ\, 10' = 7^R\, 24^\circ\, 49'\, 07''$$

Bhogyakāla = 59 *palas* (obtained as explained earlier)

The given time = 59 *ghaṭīs;* the duration of half day = $33^{gh}\ 10^{vg}$

Therefore, the given time from the sunset

$$= 59^{gh} - 33^{gh}\ 10^{vg}$$

$$= 25^{gh}\ 50^{vg}$$

= 1550 *palas*

Now, we have the given time from the sunset – *Bhogyakāla* = (1550 – 59) *palas* = 1491 *palas*

Nirayaṇa lagna = $0^R\ 29^\circ\ 37'\ 11''$ (obtained earlier)

Sāyana lagna = $1^R\ 17°\ 47'\ 11''$

Sāyana Ravi = $1^R\ 24°\ 49'\ 7''$

Here, *Lagna* < Ravi

Ravi – *Lagna* = $7°\ 1'\ 56''$

Given time = 59 *ghaṭīs*

Balance = 1 *ghaṭī*

Duration of a day = 60 *ghaṭīs*

∴ 60 – Balance = 59 *ghaṭīs* (of the previous day)

i.e., the time from sunrise = 59 *ghaṭīs*.

Note :

(i) When the Sun and *Lagna* (both *sāyana*) are in the same *rāśi*,

$$\text{the given time} = \frac{\textit{Udayamāna} \times \textit{Difference}}{30}$$

(ii) When *Lagna* < Sun, the Sun will be below the horizon. Then the given *iṣṭakāla*, since it is before the next sunrise and after the sunset of the previous day, it should be subtracted from 60 *ghaṭīs* of the previous day.

***Śloka* 6** : This *śloka* tells about the *Āyanagola* (hemisphere), *dina rātri māna* (duration of day and night) and *akṣāṁśa* (latitude).

(i) If the *sāyana* planet is within 6 *rāśis* from *Meṣa* to *Kanyā*, (i.e., from 0° to 180°) then it is said to be in the *uttaragola* (northern hemisphere).

(ii) If the *sāyana* planet is within 6 *rāśis* from *Tulā* to *Mīna* (i.e., from 180° to 360°) then it is said to be in the *dakṣiṇagola* (southern hemisphere).

(iii) If the *sāyana* Ravi is from *Karka* to *Dhanu*, then that period is called

Dakṣiṇāyana (southern course). If the *sāyana* Ravi is from *Makara* to *Mithuna*, then that period is called *uttarāyaṇa* (northern course). In fact, the *dakṣiṇāyana* of the Sun is from about June 22 to December 22 and the *uttarāyaṇa* is from December 22 to June 22 (approxly.).

(iv) When Ravi is in the *uttaragola*, adding *carapalas* to 15 *ghaṭīs*, we get *dinārdham* (half of the duration of the day time i.e., from the sunrise to noon). When Ravi is in the *dakṣiṇagola*, subtracting the *carapala* from 15 *gh*. we get the *dinārdham*.

(v) Subtracting *dinārdham* from 30^{gh}, we get *rātryārdha* (one half of the duration of the night). Multiplying *dinārdham* or *rātryārdham* by 2, we get *dinamāna* (i.e., duration of the day-time) or *rātrimāna* (i.e., duration of the night-time) respectively.

(vi) Multiply the *palabhā* of one's place by 5, and subtract $\frac{1}{10}^{th}$ of the square of the *palabhā* from the above product to get *akṣāmśa* (latitude) of one's place.

i.e., $Akṣāṃśa = 5 \times palabhā - \dfrac{(palabhā)^2}{10}$

Remark : Let p be the *palabhā* and ϕ be the latitude (*akṣāmśa*) of a place. Then from the right-angled triangle ABC (Fig. 4.1), we have

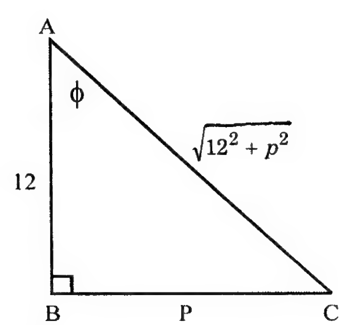

Fig. 4.1 *Akṣāṃśa*

$\tan\phi = \frac{p}{12}$ where $AB = 12$ *aṅgulas*, the height of the *śaṅku* (gnomon).

$$\therefore \qquad \phi = \tan^{-1}\left(\frac{p}{12}\right)$$

By infinite series expansion, we have

$$\theta = \frac{p}{12} - \frac{(p/12)^3}{3} + \ldots\ldots\ldots\ldots \textit{(in radian)}$$

$$= \frac{180}{\pi}\left[\frac{p}{12} - \frac{p^3}{3\times 12^3} + - \ldots\ldots\ldots\ldots\right] \textit{(in degrees)}$$

$$\approx 5p - \frac{180}{\pi\times 3\times 12^3}\, p^3$$

where the second term is of order p^3. In *GL* the second term viz. $\frac{p^2}{10}$ appears to be a small error. Thus, to a first approximation, the formula $5p$ for the latitude, is correct.

Example : Consider *palabhā*, $p = 2^{aṅg.}\ 46^{pra.} = 2.7666$ *aṅg.*

By the *GL* formula, *akṣa* $\phi = 5p - \frac{p^2}{10}$

$$= \frac{50(2.7666) - (2.7666)^2}{10} = 13^\circ.0679 = 13^\circ\ 04'$$

In fact, the *palabhā* and *akṣa* refer to Bangalore.

Example :

When *sāyana* Ravi is in the *uttaragola, carapala* = $93^{palas} = 1^{gh}\ 33^{p}$

(i) *Dinārdham* $= 15^{gh} + carapala$

$= 15^{gh} + 1^{gh}\ 33^{p} = 16^{gh}\ 33^{p}$

(ii) *Dinamānam* $= Dinārdham \times 2$

$= 16^{gh}\ 33^{p} \times 2 = 33^{gh}\ 06^{p}$

(iii) *Rātryārdha* $= 30^{gh} - Dinārdham$

$= 30^{gh} - 16^{gh}\ 33^{p} = 13^{gh}\ 27^{p}$

(iv) *Ratrimānam* $= 2 \times Rātryārdham$

$= 2 \times 13^{gh}\ 27^{p} = 26^{gh}\ 54^{p}$

(v) *Palabhā* $= 5^{ang.}\ 54^{pr.}$

Akṣāṃ śa $= 5 \times palabhā - \dfrac{(palabhā)^2}{10}$

$$= 5 \times (5|45) - \frac{(5|45)^2}{10} = \mathbf{25^\circ\ 26'\ 42''}$$

***Śloka* 7** : This *śloka* explains the *nata* and the *unnata*. It also gives the method of finding *akṣakarṇa*.

When the given time is before the noon it is *pūrva kapāla* and when it is after the noon, *paścimakapāla*.

(i) ***Unnatakāla*** : The time after sunrise in *ghaṭīs* before noon. After the noon, the time remaining for the sunset is *unnata* (see Fig. 4.2).

(ii) ***Natakāla*** : The balance after subtracting the *unnatakāla* from the *dinārdham*.

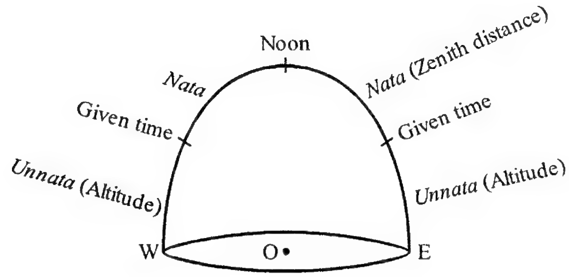

Fig. 4.2 *Natakāla* and *Unnatakāla*

Note : Zenith distance = 90° – Altitude

$$Nata = 90^\circ - Unnata$$

Example : Suppose the given time = $10^{gh}\ 30^{vg}$ from sunrise. Since the given time is before noon, it is *pūrvakapāla*.

Therefore, *Unnatakāla* = $10^{gh}\ 30^{vg}$, *Dinārdham* = $16^{gh}\ 33^{vg}$ (given)

$$Natakāla = Dinārdham - Unnatakāla$$

$$= 16^{gh}\ 33^{vg} - 10^{gh}\ 30^{vg} \quad = 6^{gh}\ 03^{vg}$$

(iii) **To find *Akṣakarṇa* :**

By adding 12 to $\dfrac{(palabh\bar{a})^2}{25}$, we get *Akṣakarṇa* in *aṅgulas*.

i.e., $Akṣakarṇa = 12 + \frac{(palabhā)^2}{25}$ *ang.*

Example : *Palabhā* = $5|45$ *aṅg.*

$\therefore Akṣakarṇa = 12 + \frac{(5|45)^2}{25} = 13^{ang.}\ 19^{pr}$

Remark : We have from Fig. 4.3,

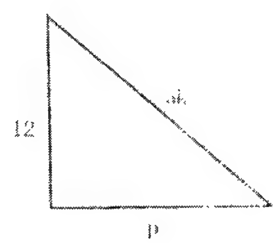

Fig. 4.3 Akṣakarṇa

$$(ak)^2 = 12^2 + p^2 = 12^2 \left[1 + (p/12)^2\right]$$

where *ak* ≡ *akṣakarṇa* and *p* ≅ *palabhā*

$$\therefore \; ak = 12\left[1 + (p/12)^2\right]^{1/2} \quad = 12\left[1 + \frac{1}{2}\,\frac{p^2}{12^2} + \ldots\ldots\right]$$

$$\approx 12 + p^2 / 24$$

GL has taken $p^2 / 25$ instead of $p^2 / 24$ with a small error.

Śloka 8 : This *śloka* explains the method of finding *hāra* and *sama* in order to get the *hara* (denominator). Then dividing the *bhājya* (numerator), explained in the next *śloka*, we obtain the *palakarṇa* (or *akṣakarṇa*). From this the *iṣṭacchāyā* is got from the corresponding right angled triangle.

(1) To find *hāra* :

(i) Divide *carapala* by 5.

(ii) If *sāyana* Ravi is in the *uttaragola*, then add 114 to the quotient obtained in step (i). The sum is called *hāra*.

(iii) If *sāyana* Ravi is in the *dakṣiṇagola*, then subtract the quotient obtained in step (i) from 114. This result gives *hāra*.

(2) To find *sama* :

(i) Add *ghaṭikārdham* (i.e., 30^{vg}) to *nata* ; take the square of the sum.

(ii) Divide the result of (i) by 2. The resulting quotient is called *sama*.

i.e., $$Sama = \frac{(30 + nata)^2}{2}$$

(3) To find *hara* :

Consider the difference between *hāra* and *sama*. Divide this difference by *Akṣakarṇa*. The result is called *hara*.

i.e., $$h\bar{a}ra = \frac{h\bar{a}ra - sama}{ak\d{s}akar\d{n}a}$$

Note : If *nata* (in *gh.*) is greater than $13^{gh}\ 30^{p}$ then take $nata\ - 13|30$.

Multiply this difference by 4. Subtract the product from *sama* obtained earlier in (2) to get true *sama*.

Example : *Cara* = 93 *palas.*

Since *sāyana* Ravi is in the *uttaragola*,

$$\text{(1) } \textit{Hāra} = 114 + \frac{cara}{5} = 114 + \frac{93}{5} = 132|36$$

(2) *Nata* = $6|3$ *ghaṭīs*

$$\textit{Sama} = \frac{(30^{\text{vig}} + \text{nata})^2}{2} = \frac{(30^{\text{vig}} + 6|3^{\text{gh}})^2}{2} = \frac{(6|33)^2}{2} = 21|27$$

(3) *Hara* is given by :

$$hara = \frac{\textit{hāra} - sama}{\textit{akṣakarṇa}}$$

$$= \frac{132|36 - 21|27}{13|19} = 8|20$$

***Śloka* 9** : This *śloka* explains the method of finding *the bhājya* (dividend) and the *iṣṭacchāya* (from the numerator and the divisor), the shadow of the gnomon at the given instant.

(1) To find *bhājya* :

(i) Divide *cara* by 10 × *palabhā*. Consider the square of the resulting quotient and multiply the square by 2.

(ii) Add 1/5 of the result obtained in step (i) to itself.

(iii) Add 114 to the sum obtained in step (ii). This result is called *bhājya* (dividend or numerator).

i.e., $$Bh\bar{a}jya = \left\{ 2\left(\frac{cara}{10 \times palabh\bar{a}}\right)^2 + \frac{2\left(\frac{cara}{10 \times palabh\bar{a}}\right)^2}{5} \right\} + 114$$

$$= \frac{6}{5} \times 2\left(\frac{cara}{10 \times palabh\bar{a}}\right)^2 + 114$$

(2) To find *iṣṭacchāyā* :

(i) Divide *bhājya* obtained as above by *hara*. The resulting quotient is called *iṣṭakarṇa* or *palakarṇa*.

(ii) Subtract 12^2 from the square of *palakarṇa*.

(iii) Take the square root of the above difference. The result obtained is called *iṣṭacchāyā*.

i.e., $$Iṣṭacch\bar{a}y\bar{a} = \sqrt{\left(\frac{Bh\bar{a}jya}{hara}\right)^2 - 144} \text{ aṅg.}$$

Example : *Palabhā* = 5|45 *aṅgulas*

Cara = 93 *palas*

(i) $$bh\bar{a}jya = \frac{6}{5} \times 2\left(\frac{cara}{10 \times palabh\bar{a}}\right)^2 + 114$$

$$= \frac{6}{5} \times 2\left(\frac{93}{10 \times 5|45}\right)^2 + 114 = 120|16$$

(ii) *hara* = 8|20 (obtained in the previous *śloka*)

$$\therefore \ \textit{iṣṭacchāyā} = \sqrt{\left(\frac{bh\bar{a}jya}{h\bar{a}ra}\right)^2 - 144}$$

$$= \sqrt{\left[\frac{120|16}{8|20}\right]^2 - 144} = 7|59|22 \ \textit{aṅgulas}$$

***Śloka* 10** : Finding *akṣakarṇa* from *iṣṭacchāya* and hence *nata* is explained in this *śloka* as follows.

(i) Add 12^2 to $(ch\bar{a}y\bar{a})^2$. Take the square root of this sum. The result obtained gives *akṣakarṇa*.

i.e., $\textit{akṣakarṇa} = \sqrt{12^2 + (ch\bar{a}ya)^2}$

(ii) Divide *bhājya* (obtained earlier) by the above *akṣakarṇa*. The quotient gives *iṣṭa hara*.

i.e., $\textit{iṣṭa hara} = \dfrac{bh\bar{a}jya}{\textit{akṣakarṇa}} = \dfrac{bh\bar{a}jya}{\sqrt{(ch\bar{a}ya)^2 + 12^2}}$

(iii) Multiply *iṣṭahara* by *akṣakarṇa*. Subtract the product from *madhyahara* (i.e., *hāra*, obtained earlier). The result gives *sama*.

i.e., $sama = madhyahara - (\textit{iṣṭahara} \times \textit{karṇa})$

(iv) Multiply the *sama* by 2, and take the square root. This gives *nata*.

Subtract $\frac{1}{2}$ *ghaṭī* (i.e., 30 *palas*) to get true *nata*.

i.e., $\quad nata = \sqrt{2 \times sama}$

True $nata = \left(\sqrt{2 \times sama}\right) - 30$ *palas*.

Note : If $2 \times sama$ is greater than 194 (i.e., if *nata* is greater than $13|30$)

then, $nata = \sqrt{\dfrac{2 \times sama - 194}{3} + (2 \times sama)}$

True $nata = nata - \frac{1}{2}$ *ghaṭī*

$= nata - 30$ *palas*

Example :

(i) $Iṣṭacchāyā = 7|59|22$ *aṅgulas*

$akṣakarṇa = \sqrt{(chaya)^2 + 12^2}$

$= \sqrt{(7|59|22)^2 + 12^2} \quad = 14|25$ *aṅgulas* $\equiv$ ***Karṇa***

(ii) $Bhājya = 120|16$

$iṣṭahara = \dfrac{Bhājya}{Karṇa} = \dfrac{120|16}{14|45} = 8|20$

(iii) *Madhyahāra* = *hāra* = $132|36$ and *akṣakarṇa* = $13|19$

$$sama = madhyahara - (iṣṭahara \times akṣakarṇa)$$

$$= 132|36 - (8|20 \times 13|19) \quad = 21|33$$

(iv) $nata = \sqrt{2 \times sama} \quad = \sqrt{2 \times (21|33)} = 6|33 \ gh.$

Subtracting $\frac{1}{2}$ *ghaṭī* (30 *palas*) we get

True *nata* = $(6|33 - 30)$ *palas* = $6|03$ *ghaṭīs.*

Example : When given *nata* > $13|30$ *ghaṭīs,* finding *iṣṭacchāyā* and conversely finding the *nata.*

Suppose *nata* = $15|10$ *ghaṭīs*

Adding $\frac{1}{2}$ *ghaṭī* i.e., 30 *palas*, we get

$$15|10^{gh.} + 30^{pa.} = 15|40 \ ghaṭīs$$

$$sama = \frac{(15|40)^2}{2} = 122|43$$

$$nata - 13|30 = 15|10 - 13|30 = 1|40$$

Spaṣṭa sama = *sama* $-$ $(4 \times 1|40) = 122|43 - 6|40 = 116|3$

hāra = $132|36$ and *akṣakarṇa* = $13|19$ *aṅgulas* (obtained earlier)

$$hara = \frac{h\bar{a}ra \text{ - } spa\d{s}\d{t}a\ sama}{ak\d{s}akar\d{n}a}$$

$$= \frac{132|36 - 116|3}{13|19} = 1|14$$

We have, *bhājya* = 120|16

$$i\d{s}\d{t}akar\d{n}a = \frac{bh\bar{a}jya}{hara} = \frac{120|16}{1|14} = 97|29 \ \textit{aṅgulas}$$

$$i\d{s}\d{t}acch\bar{a}y\bar{a} = \sqrt{(97|29)^2 - 12^2} = 96|44|30 \ \textit{aṅgulas}$$

Conversely, finding *nata* :

Suppose *chāyā* = 96|44|30 *aṅg.*

$$Kar\d{n}a = \sqrt{(ch\bar{a}y\bar{a}\ )^2 + 12^2}$$

$$= \sqrt{(96|44|30)^2 + 12^2} = 97|29 \ \textit{aṅg.}$$

Bhājya = 120|16 (given)

$$hara = \frac{bh\bar{a}jya}{kar\d{n}a} = \frac{120|16}{97|29} = 1|14$$

palakarṇa (*akṣakarṇa*) = 13|19 *aṅg.*

madhyahara (hāra) = 132|36

Sama = *madhyahara* – [(*palakarṇa* × *hara*)]

$= 132|36 - [(13|19) \times (1|14)] = 116|11$

Now, $2 \times sama = 2 \times (116|11) = 232|22 > 194$

Since $2 \times sama > 194$ we proceed as folows :

$$nata = \left[\frac{(2 \times sama) - 194}{3} + (2 \times sama)\right]^{1/2} = \left[\frac{232|22 - 194}{3} + 232|22\right]^{1/2}$$

$= 15|40$ *gh.*

True *nata* = $15|40$ *gh.* – 30 *palas* = $15|10$ *ghaṭīs.*

***Śloka* 11** : This *śloka* explains the method of finding *krānti* (declination) by using *krānti khāṇḍas*. It is as follows :

The nine *Krāntikhaṇḍas* are 40, 40, 37, 34, 30, 25, 18, 12, 4.

(i) Divide the *bhujāmśa* of *sāyana* Ravi by10.The quotient gives the number of elapsed *khaṇḍas* called *gatakhaṇḍas.*

(ii) Multiply the remainder obtained in step (i) by the *khaṇḍa* to be covered (i.e., *eṣyakhaṇḍa*). Divide the product by 10.

(iii) Add the quotient obtained from step (ii) to the sum of all elapsed *khaṇḍas.*

(iv) Divide the above sum by 10. The result gives the *krānti* (declination).

i.e., $$Kr\bar{a}nti = \frac{\left[\begin{array}{l} Sum\,of \\ gatakha\d{n}\d{d}as + \dfrac{Remainder \times E\d{s}yakha\d{n}\d{d}a}{10} \end{array}\right]}{10}$$

(see Table 4.3)

Example : Ravi = $1^R\ 5°\ 52'\ 41''$

$$\textit{Ayanāṃśa} = 18^\circ\ 10'$$

$$\textit{Sāyana}\ \text{Ravi} = 1^R\ 24^\circ\ 2'\ 41'' = 54^\circ\ 2'\ 41''$$

$$\textit{Bhujāṃśa}\ \text{of}\ \textit{sāyana}\ \text{Ravi} = 54^\circ\ 2'\ 41''$$

$$\text{Now, } \frac{\textit{Bhujāṃsa}}{10^\circ} = \frac{54^\circ\ 2'\ 41''}{10^\circ} = 5 + \frac{4^\circ\ 2'\ 41''}{10^\circ}$$

remainder = $4^\circ\ 2'\ 41''$, the quotient = 5

This implies that the number of *gatakhaṇḍas* is 5.

i.e., the *khaṇḍas* which are over are 40, 40, 37, 34 and 30.

Eṣyakhaṇḍa, the *khaṇḍa* to be covered = 25

$$\frac{\textit{Eṣyakhaṇḍa} \times \text{Remainder}}{10^\circ} = \frac{25^\circ \times 4^\circ\ 2'\ 41''}{10^\circ} = 10^\circ\ 6'\ 42''$$

Sum of the *gatakhaṇḍas* = 40 + 40 + 37 + 34 + 30 = 181

$$\textit{Krānti} = \frac{\left[\begin{array}{l}\textit{Sum of}\\ \textit{gatakhaṇḍas} + \dfrac{\textit{Eṣyakhaṇḍa}}{\textit{10}}\end{array}\right]}{\textit{10}}$$

$$= \frac{(181^\circ + 10^\circ\ 6'\ 42'')}{10} = 19^\circ\ 06'\ 40''$$

Note : For finding the declination *krānti* of a heavenly body, the argument (λ) is the *sāyana* longitude of the body. For intervals of 10° of λ, the *Grahalāghavam* gives the declinations (δ) as in Table 4.3.

Table 4.3 Declination *(krānti)*

λ	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
δ	0	40	80	117	151	181	206	224	236	240
Difference		40	40	37	34	30	25	18	12	4

The modern formula is $\sin\delta = \sin\varepsilon \sin\lambda$. for a body on the ecliptic (latitude $\beta = 0$). Now, if δ, ε and λ are in degrees, converting them into radians, we have for $\lambda = 90°$,

$$\sin\left(\frac{\delta_{max}}{180} \times \pi\right) = \sin\left(\frac{\delta \times \pi}{180}\right)$$

Since the argument is small,

$$\frac{\delta_{max}}{180} \times \pi \approx \frac{\delta \times \pi}{180}$$

i.e., $\delta_{max} \approx \varepsilon \approx 24°$

$\therefore$ $\sin\delta = 24° \sin\lambda$ for small δ.

Here, λ is the *sāyana* longitude, δ the declination and ε the obliquity of the ecliptic.

Ganeśa Daivajña has multiplied the RHS by 10 (to avoid fractions) and then the final value is divided by 10. Thus his expression is $\delta = 240 \sin\lambda$ (to be divided by 10 later). Of course, for $\sin\lambda$ he has used an approximation formula.

***Śloka* 12** : This *śloka* gives a method for finding approximate declination (*sthūla krānti*) for easy computation by using *laghu khaṇḍas*. It is as follows.

At intervals of $15°$, the six *krānti khaṇḍas* known as *laghu khaṇḍas* are given as 6, 6, 5, 4, 2, 1.

(i) Divide the *bhujāṃśa* of *sāyana* Ravi by 15. The quotient gives the number of *gatakhaṇḍas*.

(ii) Consider the product of the remainder obtained in step (i) and the *eṣyakhaṇḍa*. Divide this product by 15.

(iii) Add the sum of all the *gatakhaṇḍas* to the above quotient. This sum is the *sthūla krānti*.

i.e., $$Krānti = \left[\text{Sum of } gatakhaṇḍa + \frac{Esyakhaṇḍa \times \text{Remainder}}{15}\right]$$

Example : *Sāyana* Ravi = $1^{R}\ 24°\ 2'\ 41''$, *bhujāṃśa* = $54°\ 2'\ 41''$

Now, $$\frac{bhujāṃśa}{15°} = \frac{54°\ 2'\ 41''}{15°} = 3 + \frac{9°\ 2'\ 41''}{15°}$$

Here, quotient = 3 and remainder = $9°\ 2'\ 41''$

This implies, that the number of *gatakhaṇḍas* is 3. They are 6, 6 and 5.

$\therefore$ *eṣyakhaṇḍa* = 4.

$$Krānti = \left[\text{Sum of } gatakhaṇḍas + \frac{Remainder \times Eṣyakhaṇḍa}{15}\right]$$

$$= (6° + 6° + 5°) + \frac{9°\ 2'\ 41'' \times 4°}{15°}$$

$$= 17° + 2°\ 24'\ 43'' = \mathbf{19°\ 24'\ 43''}$$

Remark :

The formula for finding declination is given by $\delta = \sin^{-1}(\sin\varepsilon \sin\lambda)$ for the Sun. If $\lambda = 54^\circ\ 2'\ 41''$ and $\varepsilon = 24^\circ$ we get

$$\delta = \sin^{-1}(\sin 24^\circ \sin 54^\circ\ 2'\ 41'') = \mathbf{19^\circ\ 13'\ 22''}$$

The declination obtained using *krāntikhaṇḍas* is $19^\circ\ 06'\ 40''$.

The approximate declination obtained using *laghukhaṇḍas* is $19^\circ\ 24'\ 43''$.

***Śloka* 13** : This *śloka* explains the method of finding the *bhujāṃśa* of Ravi when *krānti* is known by reverse process as follows.

(i) Subtract the sum of elapsed *khaṇḍas* from *sthūlakrānti* (*krānti* obtained using *laghukhaṇḍas*).

(ii) Multiply the above difference by 15.

(iii) Divide the above product by *eṣyakhaṇḍa*.

(iv) Take the product of the number of elapsed *khaṇḍas* and 15.

(v) Add the result of step (iii) to that of step (iv). This sum gives the *bhujāṃśa* of Ravi. That is

bhujāṃśa

$$= \frac{\left(\textit{Krānti} - \begin{array}{l}\text{Sum of}\\ \text{elapsed } \textit{khaṇḍas}\end{array}\right)\times 15}{\textit{Eṣyakhaṇḍa}} + (\text{no. of elapsed } \textit{khaṇḍas} \times 15)$$

Example : *Krānti* obtained using *laghukhaṇḍas*, *sthūlakrānti* = $19^\circ\ 24'\ 43''$

and the number of the elapsed *khaṇḍas* = 3

Sum of the elapsed *khaṇḍas* = 6 + 6 + 5 = 17

Eṣyakhaṇḍa = 4

$$\textit{Bhujāṃśa} = \frac{(19^\circ\ 24'\ 43'' - 17)\times 15}{4} + (3\times 15) = \mathbf{54^\circ\ 2'\ 41''}$$

***Śloka* 14** : The method of finding *krānti* by knowing only the *dina māna* (duration of day time) without the knowledge of the position of Ravi is explained as follows.

(i) Subtract 15 *ghaṭīs* from *dinārdham* (in *gh.*). Multiply this difference by 60 to get *cara* (in *palas*).

(ii) Add $^1/_8$ of *carapala* to itself, and divide the sum by *palabhā*.

(iii) Add 25 *kalās* to the resulting quotient. This gives the *krānti* of the sun.

i.e., $$Kr\bar{a}nti = \frac{\left(carapala + \dfrac{carapala}{8}\right)}{palabh\bar{a}} + 25\ kal\bar{a}s$$

$$= \frac{9}{8} \times \frac{carapala}{palabh\bar{a}} + 25\ kal\bar{a}s$$

Note :

(i) If *dinārdham* $> 15^{gh}$, then the *krānti* is north.

(ii) If *dinārdham* $< 15^{gh}$, then the *krānti* is south.

Example : $Din\bar{a}rdham = 16^{gh}\ 33^{vig}$

$$carapala = (din\bar{a}rdham - 15^{gh}) \times 60$$

$$= (16^{gh}\ 33^{vig} - 15^{gh}) \times 60$$

$$= 93\ palas$$

$Palabh\bar{a} = 5|45$ *aṅgulas* (given)

$$Kr\bar{a}nti = \frac{9}{8} \times \frac{carapala}{palabh\bar{a}} + 25'$$

$$= \left(\frac{9}{8} \times \frac{93}{5|45}\right)^{\circ} + 25' = \mathbf{18^{\circ}\ 36'\ 44''}$$

Since *dinārdham* = $16^{gh}\ 33^{vig} > 15^{gh}$, the *krānti* is north.

***Śloka* 15** : The methods of finding *natāmśa* and *unnatāmśa* using *dinārdham* and *krānti*, without using *krānti khaṇḍas* are explained in this *śloka* as follows.

(1) Determine *krānti* and *akṣāṃśa*. Then *natāṃśa* = *krānti* $\pm$ *akṣāṃśa* = $\delta \pm \phi$, the zenith distance. Here, for northern latitude ϕ, the negative sign and for the southern ϕ, positive sign are taken. In other words, *natāṃśa* = $\delta - \phi$ where ϕ is $+^{ve}$ or $-^{ve}$ according as the place is in the northern or southern hemisphere. Similarly, the declination may also be positive or negative.

(2) *Unnatāṃśa* = [90° – *natāṃśa*], the altitude.

(3) To find *krānti* without using *krāntikhaṇḍas* :

(i) Find the *bhujāṃśa* of *sāyana* Ravi. Divide it by 10.

(ii) Subtract the result of step (i) from 18°. Multiply the difference by the result of step (i).

(iii) Divide the result of step (ii) by 72.

(iv) Subtract the result of step (iii) from $4^{\circ}\ 30'$.

(v) Divide the result of step (ii) by the result of step (iv). The quotient obtained gives the *krānti* (in *degrees*).

i.e., $$Krānti = \frac{\left(18^\circ - \frac{bhujāṃśa}{10}\right)\frac{bhujāṃśa}{10}}{4^\circ\ 30' - \frac{\left\{\left(18^\circ - \frac{bhujāṃśa}{10}\right)\times\left(\frac{bhujāṃśa}{10}\right)\right\}}{72}}$$

We shall express the above formula in a simpler form :

Let $x = \frac{Bhujāṃśa}{10}$. Then

$$Krānti = \frac{(18^\circ - x)\, x}{4^\circ.5 - \frac{[(18^\circ - x)\, x]}{72}} \text{ degrees.}$$

Example : (1) *Bhujāṃśa* of *sāyana* Ravi = $54^\circ\ 2'\ 41''$

Using the above formula,

$$Krānti \approx \frac{\left(18^\circ - \frac{54^\circ\ 2'\ 41''}{10}\right)\frac{54^\circ\ 2'\ 41''}{10}}{4^\circ\ 30' - \frac{\left\{\left(18^\circ - \frac{54^\circ\ 2'\ 41''}{10}\right)\frac{54^\circ\ 2'\ 41''}{10}\right\}}{72}} = \mathbf{19^\circ\ 9'}$$

(2) *Krānti* $\delta = 19^\circ\ 06'\ 40''$ north

Akṣāṃśa $\phi = 25^\circ\ 26'\ 42''$ in the northern hemisphere

$\therefore$ *Natāṃśa* = *Krānti* – *akṣāṃśa* $\equiv \delta - \phi$

$$= 19^\circ\ 6'\ 40'' - 25^\circ\ 26'\ 42'' = \mathbf{6^\circ\ 20'\ 2''} \text{ south.}$$

(3) *Unnatāṃśa* = 90° – *natāṃśa*

$$= 90^\circ - 6^\circ\ 20'\ 2'' = \mathbf{83^\circ\ 39'\ 58''}$$

To find *parākhya* of *natāṃśa* :

(i) Divide *natāmśa* by 6. Add the quotient to the square of itself. Divide the resulting sum by 2.

(ii) Subtract the result of step (i) from 114. The resulting difference is called *parākhya*.

i.e., $$parākhya = 114 - \frac{\left\{\left(\frac{natāṃśa}{6}\right) + \left(\frac{natāṃśa}{6}\right)^2\right\}}{2}$$

Example : *Natāṃśa* = $6^\circ\ 20'$

$$\therefore\ parākhya = 114 - \frac{\left\{\left(\frac{6^\circ\ 20'}{6}\right) + \left(\frac{6^\circ\ 20'}{6}\right)^2\right\}}{2} = 112^\circ\ 54'\ 55''$$

To find *parākhya* of *unnatāṃśa* :

The declination (*krānti*) obtained by using *laghukhaṇḍas* of *unnatāmśa* is known as *parā* (or *parākhya*) of *unnatāṃśa.*

Example : We have *unnatāṃśa* = $83^\circ\ 39'\ 58''$; its *bhujāṃśa* = $83^\circ\ 39'\ 58''$

Now, $$\frac{83^\circ\ 39'\ 58''}{15^\circ} = 5 + \frac{8^\circ\ 39'\ 58''}{15^\circ}$$

Here, quotient = 5 and remainder = $83^\circ\ 39'\ 58''$.

Therefore, from *śloka* 12 we have

the number of *gatakhaṇḍas* = 5. They are 6, 6, 5, 4 and 2. *Eṣyakhaṇḍa* = 1.

The sum of the *gatakhaṇḍas* = $6 + 6 + 5 + 4 + 2 = 23°$.

Therefore, *parā* i.e., the *krānti* of the *unnatāmśa* is given by

$$Krānti = para = \begin{array}{c}\text{Sum of}\\ gatakhaṇḍas\end{array} + \frac{Eṣyakhaṇḍa \times \text{remainder}}{15}$$

$$= 23° + \frac{1° \times 8°\ 39'\ 58''}{15°}$$

i.e., *parā* of *unnatāṃśa* = **23° 34′ 39″**

To find *yantrabhāga* from *nata* :

(i) Add $^1/_2$ *ghaṭī* to the *nata*. Multiply the sum by 15 and divide the product by *dinārdham*.

(ii) Multiply the square of the result obtained in step (i) by *parākhya* of *natāṃśa*.

(iii) Divide the result of step (ii) by 114 and add 228 to the resulting quotient.

(iv) Subtract from the above result, the *parākhya* multiplied by 2 and consider the square root of the difference obtained.

(v) Multiply the result of step (iv) by 6 and subtract 3 from this product.

The result gives *yantrabhāga*.

If p = *parākhya*, n = *nata*, d = *dinārdham*

and since $^1/_2$ *ghaṭī* = 30 *palas*, then

$$Yantrabhāga = \left[\left\{\frac{\left(\frac{(n+30)\times 15}{d}\right)^2 \times p}{114} + 228\right\} - 2p\right]^{1/2} \times 6 - 3 \text{ in degrees.}$$

Example : *Nata* $n = 6^{gh}\ 03^{vg}$ (obtained in *Śloka* 10)

dinārdham $d = 16^{gh}\ 33^{vg}$

parākhya of *natāṃśa* $p = 112^\circ\ 54'\ 55''$

$\frac{1}{2}$ *ghaṭī* = 30 *palas*

$$Yantrabh\bar{a}ga = \left[\left\{\frac{\left(\left(\frac{n+30}{d}\right)\times 15\right)^2 \times p}{114} + 228\right\} - 2p\right]^{\frac{1}{2}} \times 6 - 3$$

$$= \left[\left\{\frac{\left(\left(\frac{6|03+30}{16|33}\right)\times 15\right)^2 \times 112^\circ\ 54'\ 55''}{114} + 228\right\} - 2\times 112^\circ\ 54'\ 55''\right]^{\frac{1}{2}} \times 6 - 3$$

$$= \mathbf{33^\circ\ 32'}$$

To find *nata* using *yantrabhāga* :

(i) Add 3 to the *yantrabhāga*, and divide the sum by 6. Take the square of the result.

(ii) Add *parākhya* multiplied by 2 to the above square.

(iii) Subtract 228 from the result of step (ii).

(iv) Multiply the difference obtained in step (iii) by 114 and divide the prod-

uct by *parākhya* (of *natāmśa*).

(v) Consider the square root of the above result. Multiply it by *dinārdham.*

(vi) Divide the result of step (v) by 15 and subtract 30 *palas* from it. This gives *nata* (in *ghaṭīs*).

i.e., if $p = parākhya,\ d = dināradham$ and $y = yantrabhāga,$ then

$$nata = \left[\frac{\left\{\left(\left(\frac{y+30}{6}\right)^2 + 2p\right) - 228\right\} \times 114}{p}\right]^{1/2} \times \frac{d}{15} - 30$$

Example : Suppose *Yantrabhāga* = $33|32|0$, *parākhya* $p = 112^\circ\ 54'\ 55''$

and *dinārdham* $d = 16|33$ *gh.*

Using the above formula, we get

$$nata = \left[\frac{\left(\left(\frac{33|32+30}{6}\right)^2 + 2 \times 112^\circ\ 54'\ 55'' - 228\right) \times 114}{112^\circ\ 54'\ 55''}\right]^{1/2} \times \frac{16|33}{15} - 30$$

$$= 6^{gh}\ 03^{vig}$$

Śloka 16 : This *śloka* gives a different method for finding *iṣṭakarṇa* (*akṣakarṇa* or *palakarṇa*) from *unnatam* (in *gh.*) at a given time. It is as follows :

(i) Consider the product of *unnatam* at a given time and 90°. Divide this product by *dinārdham.*

(ii) Considering the *bhujāmśa* of the quotient obtained in step (i), find *krānti* using *laghukhaṇḍas.*

(iii) Multiply the *krānti* by *parākhya* (or *para* which refers to the diclination of *unnatāmśa* obtained using *laghukhaṇḍas*)

(iv) Divide the number 6912 by the result of step (iii). This gives the *akṣakarṇa* or *iṣṭakarṇa* in *aṅgulas.*

Example : *unnatam* at a given time = $10^{gh.}\ 30^{vig.}$; *dinārdham* = $16^{gh}\ 33^{vig}$

(i) Multiplying *unnatam* by 90 and dividing by *dinārdham*

we get

$$\frac{(10|30)\times 90}{dinardham}=\frac{945}{16|33}=57^\circ\ 5'\ 59''$$

(ii) *bhujāṃśa* of the above = $57^\circ\ 5'\ 59''$;

(iii) *krānti* of this, using *laghukhaṇḍas,* is given by

Krānti = $20^\circ\ \ 13'\ \ 35''$ (obtained as explained in *Śloka* 13)

(iv) *parākhya* = $23^\circ\ 34'\ 39''$ (obtained earlier)

Now, *parākhya* $\times$ *krānti* = $23^\circ\ 24'\ 39'' \times 20^\circ\ 13'\ 35''\ =\ 476|53|12$

(v) *palakarṇa* = $\dfrac{6912}{476|53|12}$ = **14|29 *aṅgulas***

***Śloka* 17** : The inverse process of finding *unnatam* from *palakarṇa* is explained as follows.

(i) Divide the number 6912 by *palakarṇa*

(ii) Divide the result of step (i) by *parākhya* (declination of *unnatāmśa*) The result gives *krānti*.

(iii) Find *bhujāṃśa* of the *krānti* obtained above as given by *Śloka* 13.

(iv) Multiply the *bhujāṃśa* by *dinārdham* and divide by 90. The result gives *unnatām*.

i.e., $$unnatam = \frac{dinardhām \times bhujāṃśa \text{ of } kranti}{90}$$

$$\text{where } krānti = \frac{\left(6912 / palakarṇa\right)}{parākhya}$$

Example : *Dinārdham* = $16|33$ *gh.*

and *Palakarṇa* = $14|29$ *aṅg.*

Parākhya = $23^\circ\ 34'\ 39''$

$$Krānti = \frac{\left(6912 / 14|29\right)}{23^\circ\ 34'\ 39''} = 20^\circ\ \ 14'\ \ 37''$$

The *bhujāṃśa* for the above *krānti* = $57^\circ\ 9'\ 15''$ (obtained by inverse process)

$$Unnatam = \frac{16|33 \times 57^\circ\ 9'\ 15''}{90^\circ} = \mathbf{10^{gh}\ 30^{vig}}$$

Śloka 18 : The method of finding *unnatakāla* when the *unnatāmśa* obtained from *yantrabhāga* is known is explained as given below.

(i) Find the declination (*krānti*) of *unnatāmśa* obtained from *yantrabhāga*. Multiply this *krānti* by 24 and divide by *parākhya* (declination of *unnatāmśa*).

(ii) Find the *bhujāṃśa* of the above result and multiply it by *dinārdham* and divide the product by 90. The result gives *unnatakāla*.

For the *pūrva kapāla* (eastern hemisphere) the *unnatakāla* obtained will be the elapsed *ghaṭīs* (*gataghaṭī*) and for the *paścima kapāla* (western hemisphere) the *unnatakāla* is the remaining *ghaṭīs* to be covered.

Example : *yantrabhāga* = $55|45|48$

declination of the above = $19^\circ\ 52'\ 13''$

parākhya = $23^\circ\ 34'\ 39''$

Now, $\dfrac{\text{declinatio n} \times 24}{\textit{parākhya}} = \dfrac{(19|52|13) \times 24}{23|34|39} = 20^\circ\ 13'\ 25''$

bhujāṃśa from the above *krānti* = $57^\circ\ 05'\ 52''$

Now, $\dfrac{\textit{bhujāṃśa} \times \textit{dinārdham}}{90} = \dfrac{(57|05|52) \times (16|33)}{90}$

unnatakāla = $\mathbf{10^{gh}\ 30^{vig}}$

Since we have obtained *unnatakāla* in *pūrva kapāla*, it gives the elapsed *ghaṭīs*.

***Śloka* 19** : This *śloka* explains the inverse process of finding *yantrabhāga* using *unnataghaṭī*. It is explained below.

(i) Multiply *unnataghaṭī* (i.e., *unnata* in *ghaṭīs*) by 90°, and divide it by *dinārdham*.

(ii) Determine the *krānti* of the above quotient using *laghukhaṇḍas*.

(iii) Multiply the *krānti* and *parākhya* and divide by 24.

(iv) The *bhujāmśa* for the above result is called *yantrabhāga*.

Example : *Unnatam* = $10^{gh}\ 30^{vig}$, *dinārdham* = $16^{gh}\ 33^{vig}$

(i) $\dfrac{unnatam \times 90}{din\bar{a}rdham} = \dfrac{10^{gh.}\ 30^{vig} \times 90^{\circ}}{16^{gh.}\ 33^{vig}} = 57^{\circ}\ 5'\ 58''$

(ii) *bhuja* of the above = $57^{\circ}\ 5'\ 58''$

krānti (of this using *laghukhaṇḍas*) = $20^{\circ}\ 13'\ 35''$

(iii) *parākhya* = $23^{\circ}\ 34'\ 39''$

$$\frac{par\bar{a}khya \times kranti}{24} = \frac{23^{\circ}\ 34'\ 39'' \times 20^{\circ}\ 13'\ 35''}{24} = 19^{\circ}\ 52'\ 13''$$

(iv) *bhujāṃśa* for the result of (iii) [See *Śloka* 13]

yantrabhāga = $\mathbf{55^{\circ}\,45'\,48''}$

***Śloka* 20** : The method of finding *iṣṭakarṇa* from *yantrabhāga* and the inverse process of finding *yantrabhāga* from *iṣṭakarṇa* is explained in this *śloka* as follows.

(i) Find the declination of the given *yantrabhāga*. Divide 288 by the declination of *yantrabhāga* obtained above. The result gives the *iṣṭakarṇa*.

i.e., $\quad I\d{s}\d{t}akar\d{n}a = \dfrac{288}{kr\bar{a}nti\ of\ yantrabh\bar{a}ga}$

(ii) Divide 288 by the given *iṣṭakarṇa*. Find *bhujāmśa* of the resulting quotient. This gives *yantrabhāga*.

i.e., $\quad yantrabh\bar{a}ga = bhuj\bar{a}\d{m}\acute{s}a \text{ of } \left(\dfrac{288}{i\d{s}\d{t}akar\d{n}a}\right)$

Example :

(i) given *yantrabhāga* = $55|45|48$

Krānti (declination) of the *yantrabhāga* = $19°\ 52'\ 12''$

$$\textit{iṣṭakarṇa} = \frac{288}{19°\ 52'\ 12''} = 13|56|38 \textit{ aṅgulas}$$

(ii) given *iṣṭakarṇa* = $13|56|38$ *aṅgulas*

$$\text{Now, } \frac{288}{13|56|38} = 19|52|12$$

bhujāṃśa for $(19|52|12) = 55|45|48$

i.e., *yantrabhāga* = **55|45|48**

Remark :

Here the maximum declination (*parama krānti*) is $24°$. Therefore,

$$\textit{Yantrabhāga} = \textit{Bhujāṃśa} \text{ of } \frac{24 \times 12}{\textit{Iṣṭakarṇa}}$$

$$\text{and} \quad \textit{Iṣṭakarṇa} = \frac{288}{\textit{Yantrabhāga}}$$

***Śloka* 21** : Now, determination of directions is explained.

On an even level ground a circle is drawn. The *śaṅku* (gnomon) is fixed at the centre. The line joining the entry and exit points of the shadow (on the circle) determines the *west* and the *east* directions respectively. The perpendicular line, through the centre, to the east-west line provides the north and south directions.

***Śloka* 22** : A different method of finding *bhuja* in order to know the *direction* (*dik*) is explained as follows.

(i) Find the declination of the Sun at the given time and multiply it by *palakarṇa*.

(ii) Multiply the above product by *chāyākarṇa*.

(iii) Divide the product obtained in step (ii) by 350, to get *bhuja* in the direction of the Sun.

(iv) The above *bhuja* is added to or subtracted from the product 2 × *palabhā*. This gives the corrected *bhuja* (*spaṣṭa bhuja*).

Note : In step (iv) take the sum if *palabhā* and *bhuja* are in the same direction and the difference if they are in different directions.

Example : Given time from sunrise = $10^{gh}\ 30^{vgh}$

Sāyana Sun at the given time = $1^{R}\ 5°\ 52'\ 41''$

Declination (*krānti*) of the Sun = $19°\ 6'\ 40''$

Palakarṇa = $13|19$ *aṅgulas*

Chāyākarṇa = $14|25$ *aṅgulas*

We have

(*Krānti* × *Palakarṇa*) × *Chāyākarṇa*

$$= (19|6|40) \times (13|19) \times (14|25) = 3668|59|8$$

i.e., $$bhuja = \frac{3668|59|8}{350} = 10|28$$

palabhā = $5|45$ *aṅgulas* (given)

Since *sāyana* Ravi and *palabhā* are in different directions, we have

$$\textit{spaṣṭa bhuja} = (2 \times \textit{palabhā}) - \textit{bhuja}$$

$$= (2 \times 5|45) - 10|28$$

$$= \mathbf{1|02} \text{ (south)}$$

***Śloka* 23** : A different method of finding *digaṃśa* in order to find *dik* is explained as follows.

(i) Multiply the difference between *dinamāna* and 30 by 11. This result is positive or negative according as *dinamāna* is greater than or less than 30 *ghaṭīs* respectively.

(ii) Find the *krānti* (declination) of *yantrabhāga* using *laghukhaṇḍas*. This declination is always negative (south).

(iii) If the results of step (i) and step (ii) have the same sign, consider their sum ; if they are in different signs take the difference between them.

(iv) Multiply the result obtained in step (iii) by 8, and divide this product by the declination of the difference between 90° and *yantrabhāga*.

(v) The *bhujāṃśa* of the above result is called *digaṃśa*.

i.e.,*digaṃśa* = *Bhujāṃśa* of

$$\frac{[(\textit{dinamāna} - 30) \times 11 \pm \textit{declination of yantrabhāga}] \times 8}{\textit{declination of}(90^\circ - \textit{yantrabhāga})}$$

Example : *Dinamāna* = 33|6 *ghaṭīs*

(i) $[(\textit{dinamāna}) - 30] \times 11 = \left(33^{gh}|6^{vgh} - 30^{gh}\right) \times 11$

$$= 3|6 \times 11$$

$$= +34|6$$

Since *dinamāna* > 30, the result is positve.

(ii) *yantrabhāga* = $55^\circ\ 45'\ 48''$ (given)

declination of the above = $-19^\circ\ 52'\ 13''$ which is always taken south.

(iii) Now, $34|6 - 19|52|13 = 14|13|47$

since the results of (i) and (iii) are of opposite signs,

(iv) declination of $(90^\circ - 55|45|48) = 13|24|44$

and $\dfrac{(14|13|47) \times 8}{13|24|44} = 8|29|15$.

(v) *Digaṃśa bhujāṃśa* of $8|29|15 = \mathbf{21^\circ\ 13''}$ (as explained in *Śloka* 13).

***Śloka* 24** : This *śloka* explains the method of finding *dik* (directions) from *digamśa*.

Tūriya yantra is an instrument with a circular base, calibrated in degrees, and two mutually perpendicular strips (indicating the east-west and north-the south lines). For fixing the (four) directions, circular base of this instrument is placed horizontally on an even ground surface. Then, with the foot of the *śaṅku* (gnomon) coinciding with the centre of the *tūriya yantra*, measure an angle equivalent to the *digamśa* (obtained from earlier *śloka*) from the shadow line to the *śaṅku*. Thus, the line at that angle will be the actual east-west line. The direction perpendicular to it will be the north-south direction.

***Śloka* 25** : For the fixing of *nalikā* (tube) instrument finding the *bhuja* and *koṭi* is explained.

For the planet to be observed, its true declination (*spaṣṭa krānti*) has to be determined. The true declination is multiplied by the *iṣṭa karṇa* and *pala karṇa* (i.e., *akṣa karṇa*). The product is divided by 700. The result is the required *bhuja* in the direction of the *krānti* which should be corrected with the southern *palabhā*. This gives the *spaṣṭa bhuja*. Subtract

the square of the *spaṣṭa bhuja* from the square of the *iṣṭa chāyā* and take the of square-root of this difference. This gives the *spaṣṭa koṭi*.

Example 1 : *Samvat* 1669, *Śaka* 1534, *Vaiśākha Śukla Paurṇimā* (15th *tithi*), Monday at 57 *ghaṭīs* from the sunrise, the fixing of the *nalikā* for observing *Kuja* is explained. The place of observation is Kāśī.

After the usual corrections, we have

true Sun is $1^R\ 6°\ 37'\ 12''$ and true Kuja is $11^R\ 6°\ 37'\ 29''$.

Karṇa = $11|48|40$, *Krānti* = $23°\ 44'\ 59''$ (south), *Śara* (south) = $46|14|34$ *aṅg.*

Subtracting 3^R (i.e., $90°$) from true Kuja, we get $8^R\ 6°\ 37'\ 29''$.

For this, the *Krānti* $\delta = 23°\ 47'\ 29''$ (south). *Akṣāṃśa* (latitude) of kāśī ϕ = $25°\ 26'\ 42''$ (north).

$\therefore$ *Natāṃśa* = $\delta - \phi = 49°\ 14'\ 11''$ (south)

Dṛkkarma = $118'\ 44''$. The *dṛkkarma* corrected *Kuja* = $11^R\ 8°\ 36'\ 13''$.

For this position of *Kuja*, the *Krānti* = $1|17|30$

Śara corrected *Krānti* i.e., *spaṣṭa krānti* = $3|1|33$

Iṣṭaghaṭī = 57 *gh.*, *dinamānam* = $33|10$ *gh.*

Ravibhogyakāla = 59 *gh.*, *Lagna* = $0|15|23|21$

Bhogyakāla of *dṛkkarma* corrected *Kuja* = 18 *gh.*

dinagatakāla of *Kuja* = $4|29$ *gh.*

Cara of the corrected Kuja = 6

Corrected *cara* = 14.

Dinamānam = $29|32$ *gh.*

Cor. *Natāṃśa* = $28^\circ\ 28'\ 15''$

Unnatāṃśa = $61^\circ\ 31'\ 45''$ (complement of *Natāṃśa*)

Parākhya = $21|12|14$

Unnatam = $4|29$

Multiplying this by 90 and dividing by *dinārdham* (i.e., $14|46$ *gh.*) we get *phala* = $27|19|37$ degrees.

Krānti of the above *phala* = $10^\circ\ 42'\ 36''$.

Multiplying this *krānti* by *parākhya*, we get $227|5|37$. Dividing this by 6912, we have

Iṣṭakarṇa = $30|26$

Akṣakarṇa = $13|19$

$$Bhuja = \frac{(Akṣa\ karṇa \times (Iṣṭakarṇa) \times krānti}{700}$$

$$= \frac{(13|19)\,(30|26)\,(3|1|33)}{700} = 1|45 \text{ aṅgulas}$$

Since the *krānti* is south, the *bhuja* is also south. *Palabhā* = $5|45$ *aṇgulas.*

Palabhā corrected *spaṣṭa bhuja* $= 1|45 + 5|45 = 7|30$ *aṅgulas.*

Squaring the *spaṣṭa bhuja*, we get $56|15$.

$$Iṣṭa\ chāyā = \sqrt{(Iṣṭakarṇa)^2 - (12)^2}$$

$$= \sqrt{926|11 - 144}$$

$$= 27|58\ aṅgulas$$

$$(Chāyā)^2 = 782|11$$

$$Koṭi = \sqrt{(Chāyā)^2 - (Spaṣṭabhuja)^2}$$

$$= 26|56\ aṅgulas$$

***Śloka* 26** : Now, fixing of the *nalikā* is explained.

Knowing all the directions on an even level ground, according as the planet is in western or eastern hemisphere, the angle equal to the *koṭi* is measured westward or eastward from the east-west line. From this, equal to the *bhuja*, towards the north or south, the length is measured. The line joining the end points of the *karṇa* and *bhuja* gives the *chāyā*. (This is the hypotenuse). The line joining end of the *chāyā* and the top of the *śaṅku is* the direction for the *nalikā yantra* to observe the planet in the sky. The line joining the top of the *śaṅku*, fixed at the central point, and the end of the *chāyā* (shadow) gives the direction for fixing the *nalikā* to observe the planet's reflection in water.

CHAPTER 5

CANDRAGRAHAṆĀDHIKĀRAḤ

(Lunar Eclipse)

Śloka 1 : This *śloka* explains the method of finding the true longitude of planets at a given time (*iṣṭakāla*). In this case we consider the bodies, Ravi, Candra and Rāhu.

(i) Multiply the motion of the planet which is expressed in *kalās* by *gata ghaṭī* or *eṣyaghaṭī* (as the case is) and divide by 60.

(ii) Correspondingly add (or subtract) the result of (i) to (or from) the mean longitude. This gives the mean longitude of the heavenly body.

Note : While finding the mean position of a body, if the given time (*iṣṭkāla*) is after the sunrise, then the *gata* (elapsed) time in *ghaṭīs* must be used in (i) above and added in (ii).

On the otherhand, if the given time is before the sunrise, then the *eṣyaghaṭī* (to be covered) must be subtracted in item (ii).

From the mean positions of the Sun and the Moon, applying the prescribed equations, the true positions are determined. From these the instant of true full-moon (*śukla parvānta*) is found out as follows :

Subtract the true longitude of the Moon from that of the Sun, divide the difference by the difference between the true daily motions of the Moon and the Sun and then multiply the quotient by 60 to get the *ghaṭīs* to be covered for the *śukla parvānta* from the *iṣṭakāla*. That is, if S and M are the true longitudes of the Sun and the Moon at time t_0 gh. (*iṣṭakāla*) and DS and DM are their true daily motions then the instant of the (*śukla*) *parvānta* is given by

$$\left[t_o + \frac{S + 6^R - M}{DM - DS} \times 60\right] \textit{ghaṭīs}.$$

At the instant of the *parvānta*, the true longitudes of the Sun, the Moon and the ascending node (*Rāhu*) of the Moon are determined.

Example : *Vikrama Samvat* 1677, *Śālivāhana Śaka* 1542 *Mārgaśira Śukla Pūrṇimā* Wednesday. *Cakra* = 9, *Ahargaṇa* = 636.

This corresponds to December 9, 1620 (G).

At the sunrise, we have

Mean Sun = $8^R\ 0°\ 8'\ 59''$

Mean Moon = $1^R\ 25°\ 19'\ 57''$

Mean Rāhu = $7^R\ 28°\ 25'\ 27''$

According to that year's *Pañcāṅga*, the end of *Pūrṇimā tithi* is at $38|11$ gh. (after the sunrise). The true postions of the heavenly bodies at that instant are

True Sun = $8^R\ 0°\ 9'\ 26'' = S$

True Moon = $1^R\ 29°\ 36'\ 06'' = M$

True daily motion of the Sun, DS = $61'\ 11''$

True daily motion of the Moon, DM = $824'\ 05''$

Therefore, the instant of *parvānta* t_p is given by

$$t_p = \left[t_o + \frac{S + 6^R - M}{DM - DS} \times 60\right] \text{gh.}$$

where $t_o = 38|11$ gh. (after the sunrise)

$$\therefore \qquad t_p = 38|11 + \frac{33'\,20''}{762'\,54''} \times 60 = 40|48 \text{ gh. (after sunrise).}$$

i.e. $2^{gh}\ 37^{vig}$ after the *iṣṭakāla*, $38|11$ gh.

Now, at the instant of *Parvānta*, we have true Sun = $8^R\ 0°\ 12'\ 06''$

true Moon = $2^R\ 0°\ 12'\ 01''$ and Rāhu = $7^R\ 28°\ 23'\ 18''$

Śloka 2 : This *śloka* explains the method of finding *śara* (latitude) of the Moon and the possibility of an eclipse.

(i) Find the true longitudes of the Sun, the Moon and Rāhu at the *Parvānta*.

(ii) Consider (Sun – Rāhu). This result is called *virāhvarka*. If this is less than $14°$ then there is a possibility of an eclipse. If this is greater than $14°$, then there is no chance of an eclipse.

(iii) Divide the above difference (*virāhvarka*) by 7 and multiply it by 11. The result obtained is known as *śara* (latitude) of the Moon which will be in *angulas*. The direction of *śara* is the same as that of *virāhvarka*. (i.e., if *virāhvarka* is less than $180°$, *śara* is the $+^{ve}$ and otherwise $-^{ve}$)

i.e., $$\acute{S}ara = \frac{11}{7} \times (\text{Sun} - \text{Rāhu})$$

Remark : *GL* uses the approximation

$$120 \sin\theta \approx \frac{72}{35}\theta$$

Let S and R be the true longitudes of the Sun and Rāhu.

Then we know that latitude $\beta = 270' \sin(S - R)$

$$\approx \frac{270 \times 72}{120 \times 35}(S - R) \approx \frac{11}{7}(S - R)$$

Example : At the *parvānta*, we have

True Sun = $8^R\ 0°\ 12'\ 6''$ and Rāhu = $7^R\ 28°\ 23'\ 18''$

Virāhvarka = Sun – Rāhu = $0^R\ 1°\ 48'\ 48''$

Bhuja of virāhvarka = $1°\ 48'\ 48'' < 14°$.

Therefore there is a possibility of an eclipse.

Now, we have

$$\text{Śara} = \frac{11}{7}\ (\text{Sun} - \text{Rāhu}) = \frac{11}{7}\ (1°\ 48'\ 48'') = 2|50\ \textit{aṅgulas}$$

Since *virāhvarka* is in the *uttaragola* (i.e., less than 180°), the *śara* is also in the *uttaragola* and hence positive.

Śloka 3 : This *śloka* gives the methods of finding *Sūryabimbam* (Sun's diameter), *Candrabimbam* (Moon's diameter) and *bhūchāyābimbam* (diameter of the earth's shadow).

(i) *Sun's* (angular) diameter,

$$\text{Sūryabimbam} = \left[\frac{DS - 55}{5} + 10\right]\ \textit{aṅgulas}$$

where DS is the Sun's true daily motion in ***kalās***.

(ii) Moon's (angular) diameter,

$$Candrabimbam = \frac{DM}{74} \text{ aṅgulas}$$

where DM is the true daily motion of the moon in *kalās*.

(iii) The angular diameter of the earth's shadow cone,

Bhūchāyābimbam

$$= \left[\left(\frac{3}{11} \times \text{Moon's diameter}\right) + (3 \times \text{Moon's diameter}) - 8\right] \text{ aṅg.}$$

According to the commentator Viśvanātha, the expressions for the angular diameters of the Sun, the Moon and the earth's shadow cone are as follows :

(1) The Sun's diameter, $d_s = \dfrac{2\,DS}{11}$ *aṅgulas*

(2) The Moon's diameter, $d_m = \dfrac{DM}{74}$ *aṅgulas*

(3) Diameter of the earth's shadow cone

$$d_e = \left[\frac{DM - 716}{22} + 32 - \frac{DS}{7}\right] \text{ aṅgulas}$$

$$= \left[\frac{DM}{22} - \frac{DS}{7} - \frac{6}{11}\right] \text{ aṅgulas}$$

Example : $DS = 61'\,11''$, $DM = 824'\,05''$

Therefore, we have the diameters of the Sun, the Moon and the earth's shadow given by

(1) $d_s = 11|7$ *aṅgulas*, (2) $d_m = 11|8$ *angulas* and (3) $d_e = 28|10$ *aṅgulas*.

Śloka 4 : This *śloka* explains *mānaikya khaṇḍa* and *grāsa*.

In the case of a lunar eclipse the earth's shadow is called *chādaka* (the eclipser) and the Moon is called *chādya* (the eclipsed).

We define

$$\textit{Mānaikya khaṇḍa} = \frac{1}{2}\,[\textit{Chādaka bimbam} + \textit{Chādya bimbam}]$$

$$= \frac{1}{2}\,[\text{shadow diameter + Moon's diameter}]$$

Also, *grāsa* (the covered portion) is given by *grāsa* = *Mānaikya khaṇḍa* – *Śara* and *khagrāsa* is given by *khagrāsa* = *grāsa* – Moon's diameter.

Note :

(i) If it is not possible to subtract *Śara* from *mānaikya khaṇḍa* (i.e., when *śara* > *mānaikyakhaṇḍa*), then there will be ***no eclipse.***

(ii) If the *grāsa* is greater than the *chādya bimbam* (ie Moon's diameter) then the ***eclipse is total.***

Example : Suppose the earth shadow's diameter

Chādaka bimbam = $28|10$ *aṅgulas* and

the moon's diameter, *Chādya bimbam* = $11|8$ *aṅgulas*. Then

(i) *Mānaikya khaṇḍa* = $\left(\frac{28|10 + 11|8}{2}\right) = 19|39$ *aṅgulas*

Śara = 2|50 *aṅgulas*

(ii) *Grāsa* = *Mānaikya khaṇḍa* – *śara*

= 19|39 – 2|50 = 16|49 *aṅgulas*

(iii) *Khagrāsa* = *grāsa* – Moon's diameter

= 16|49 – 11|7 = 5|42 *aṅgulas*

In this case, *grāsa* > Moon's diameter. Therefore the lunar eclipse is ***total***.

Śloka 5 : This *śloka* explains the method of finding *sthiti* (the half duration of the eclipse) and *marda* (the half duration of totality). It is as given below.

To find sthiti :

(i) Add *śara* to the *mānaikya khaṇḍa* and multiply the sum by 10.

(ii) Multiply the above result by *grāsa* and take the square-root of the product.

(iii) Subtract $\frac{1}{6}$th of the result obtained in step (ii) from itself.

(iv) Divide the above value by the diameter of the Moon. The result obtained is called *spaṣṭa sthiti* and it will be in *ghaṭīs*.

That is, if *grāsa* = *g*, *mānaikya khaṇḍa* = *m*, *śara* = *s* and the Moon's diameter = d_m, then

Spaṣṭa sthiti = half duration of the eclipse

$$= \frac{[(s+m)10 \times g]^{1/2} - \dfrac{[(s+m)10 \times g]^{1/2}}{6}}{d_m} = \frac{\frac{5}{6} \times [(s+m) \times 10 \times g]^{1/2}}{d_m} \text{ gh.}$$

To find *marda* :

(i) Consider half of the *difference* between the diameters of the earth's shadow and of the Moon.

(ii) Add *śara* to the above and multiply it by *khagrāsa*.

(iii) Multiply the result of step (ii) by 10 and take the square root.

(iv) Add $\frac{1}{6}^{th}$ of the result obtained above to itself.

(v) Divide the above result by the Moon's diameter. This gives *marda* in *ghaṭīs*.

That is, if the diameter of earth's shadow = d_e, *khagrāsa* = *kg*, *śara* = *s* and the Moon's diameter = d_m then

Marda = Half duration of totality

$$= \frac{\left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2} - \frac{\left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2}}{6}}{d_m}$$

$$= \frac{\frac{5}{6} \times \left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2}}{d_m} \text{ ghaṭīs}$$

Half-Durations of Eclipse and of Maximum Obscuration :

The next important step is to determine the instants of the beginning and the end of a lunar eclipse as also of the maximum obscuration. For this, we need to find the duration of the first half and

the second half of the total duration of the eclipse. This is explained in Fig. 5.1.

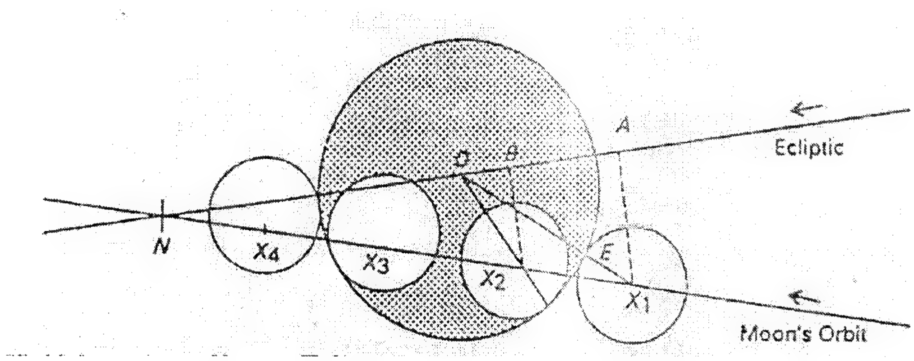

Fig 5.1: Half-duration of Lunar eclipse

A half-duration is the time taken by the Moon, relative to the Sun, so that the point A in the figure moves through OA. We have

$$OA^2 = OX_1^2 - AX_1^2 = (OE + EX_1)^2 - AX_1^2 = (d_1 + d_2)^2 - \beta_1^2$$

where

$OE = d_1$ = Semi-diameter of the shadow

$EX_1 = d_2$ = Semi-diameter of the Moon

$\beta_1 = AX_1$ = Latitude of the Moon (*vikṣepa* or *śara*)

When the Moon's centre is at X_1, we have

$$\text{Half-duration} = \frac{\sqrt{(d_1 + d_2)^2 - \beta_1^2}}{(\text{Moon's daily motion} - \text{Sun's daily motion})}$$

Since the actual moment of the beginning of the eclipse, and hence

the Moon's latitude then, are not known, the above formula is used iteratively.

By a similar analysis, the half-duration of maximum obscuration (or totality as the case may be) is given by

$$\text{Half-duration of max. obsn.} = \frac{\sqrt{(d_1 \sim d_2)^2 - \beta_1{}^2}}{(DM - DS)}$$

where *DM* and *DS* are the true daily motions of the Moon and the Sun, respectively.

The, thus obtained half-duration of the eclipse and the maximum obscuration are :

(1) subtracted from the instant of the opposition to get the first moments; and

(2) added to the instant of the opposition to obtain the last moments.

Finally, the magnitude (*pramāṇam*) of the eclipse is given by

$$\text{Magnitude} = \frac{\textit{Amount of obscuration(Grāsa)}}{\textit{Angular diameter of the Moon}}$$

Obviously, if the magnitude is greater than or equal to 1, then the eclipse is total; otherwise, it is partial.

It is also clear, from Fig. 5.1, that if the sum of the angular semi-diameters of the Moon and the shadow is less than the latitude of the Moon, there will be no eclipse.

Example : *Śara*, $s = 2|50$ *aṅgulas*

Manaikya khaṇḍam, $m = 19|38$ *aṅgulas*.

$$\textit{grāsa}, \ g = 16|48 \ \textit{aṅgulas}.$$

$$\textit{khagrāsa}, \ kg = 5|41 \ \textit{aṅgulas}.$$

$$\text{Moon's diameter}, \ d_m = 11|7 \ \textit{aṅgulas}$$

$$\text{Earth shadow's diameter}, \ d_e = 28|10 \ \textit{aṅgulas}$$

$$\therefore \ Sthiti = \frac{5}{6} \frac{\left[(s+m) \times 10 \times g\right]^{1/2}}{d_m} \ \textit{ghaṭīs} = 4|\mathbf{36} \ \textbf{\textit{ghaṭīs}}$$

$$Marda = \frac{\frac{5}{6}\left[\left(\left(\frac{d_e - d_m}{2}\right) + s\right) \times 10 \times kg\right]^{1/2}}{d_m} \ \textit{ghaṭīs} = \mathbf{1}|\mathbf{54} \ \textbf{\textit{ghaṭīs}}$$

Śloka 6 : The methods of finding *sparśa sthiti*, (first half duration of the eclipse), *mokṣa sthiti* (second half duration of the eclipse) and *sammīlana marda* (first half of totality) and *mokṣa marda* or *unmīlana* (second half of totality) are explained as follows.

(i) Find the *bhuja* of *vyagu* (true longitude of the Sun – true longitude of Rāhu). Multiply this bhuja of *vyagu* by 2. Express the product in *palas* (*vighaṭīs*).

Note : The word *vyagu* (*vi* + *agu*) means true Sun – Rāhu. Here, *agu* means Rāhu. If vyagu is in the even quadrant (II or IV i.e., $90^\circ < vyagu < 180^\circ$ or $270^\circ < vyagu < 360^\circ$) then the above product is respectively subtracted from and added to *sthiti* in *ghaṭīs* to get *sparśa sthiti* and *mokṣa sthiti*.

i.e., *sparśa sthiti* = *sthiti* – 2 × *bhuja of vyagu*

mokṣa sthiti = *sthiti* + 2 × *bhuja of vyagu*

Carry out the same operations by considering *marda* in the place of *sthiti*. This gives the *sammīlana marda* and the *mokṣa marda* or *unmīlana marda*.

i.e., *sammīlana marda* = *marda* – 2 × *bhuja of vyagu*

mokṣa marda = *marda* + 2 × *bhuja of vyagu*

If *vyagu* is in the odd quadrant (I or III i.e., $0 < vyagu < 90^\circ$ or $180^\circ < vyagu < 270^\circ$) then $2 \times bhuja$ is added to *sthiti* to get *sparśa sthiti* and it is subtracted from *sthiti* to get *mokṣa sthiti*.

The same rule holds in the case of *sammīlana* and *mokṣa marda* also considering *marda* instead of *stithi*.

Note : *Vyagu* is also called *virāhvarka*.

Example : *Sthiti* = $4|36$ *ghaṭīs*

Vyagu = $1^\circ\ 48'\ 48''$

bhuja of vyagu = $1^\circ\ 48'\ 48''$

$2 \times bhuja = 3|37|36 \approx 3$ *vighaṭīs*

marda = $1|54$ *ghaṭīs*

Since the *vyagu* is in first quadrant,

sparśa sthiti = First half-duration

$= sthiti + 2 \times bhuja$

$$= 4^{gh}\ 36^{vig} + 3^{vig} = \mathbf{4|39}\ \textbf{\textit{ghaṭīs}}$$

mokṣa sthiti = Second half-duration

$$= sthiti - 2 \times bhuja$$

$$= 4^{gh}\ 36^{vig} - 3^{vig} = \mathbf{4|33}\ \textbf{\textit{ghaṭīs}}$$

sammīlana marda = *marda* + 2 × *bhuja*

$$= 1^{gh}\ 54^{vig} + 3^{vig} = 1^{gh}\ 57^{vig}$$

mokṣa marda = *marda* − 2 × *bhuja*

$$= 1^{g}\ 54^{vig} - 3^{vig} = \mathbf{1|51}\ \textbf{\textit{ghaṭīs}}$$

Śloka 7 : This *śloka* explains about the *madhyakāla* (*parvānta* or middle of the eclipse), *sparśakāla* (beginning of the eclipse) and *mokṣakāla* (end of the eclipse) as follows.

(i) The *parvānta* is the middle of the eclipse or *madhyakāla*.

(ii) By subtracting sparśa sthiti from the *madhyakāla*, we get *sparśakāla*

i.e., *sparśakāla* = *madhyakāla* – *sparśa sthiti*

(iii) By adding the *mokṣa* sthiti to the *madhyakāla*, we get the *mokṣakāla*.

i.e., *mokṣakāla* = *madhyakāla* + *mokṣa sthiti*

(iv) Similarly, for a total elipse, we have

sammīlanakāla = *madhyakāla* – *sammīlana marda*

and *unmīlanakāla* = *madhyakāla* + *unmīlana marda*

Example : We have already obtained

Madhyakāla = 40|48 *ghaṭīs* (after sunrise)

Sparśa sthiti = 4|39 *ghaṭīs*

Mokṣa sthiti = 4|33 *ghaṭīs*

Sammīlana marda = 1|57 *ghaṭīs*

Unmīlana marda = 1|51 *ghaṭīs*

Now, therefore we get

Sparśakāla = 36|09 *ghaṭīs*

Mokṣakāla = 45|21 *ghaṭīs*

Sammīlanakāla = 38|51 *ghaṭīs*

and *Unmīlanakāla* = 42|39 *ghaṭīs*

Śloka 8 : This *śloka* explains the method of finding *grāsa* at a given time (*iṣṭaghaṭī*).

(i) Multiply *grāsa* by *iṣṭaghaṭī* and divide the product by *sparśa sthiti*.

(ii) Add 1|15 *aṅgula* to the above result. This gives *grāsa* at *iṣṭakāla*.

i.e., $\textit{grāsa}$ at $\textit{iṣṭakāla} = \left[\dfrac{\textit{grāsa} \times \textit{iṣṭaghati}}{\textit{sparśa sthiti}}\right] + 1|15$ in *aṅgulas*

This is the *grāsa* at *iṣṭakāla* after *sparśakāla* (before *madhyakāla*). If *mokṣa sthithi* is used in the place of *sparśa sthiti* then we get *grāsa* at *iṣṭakāla* before *mokṣakāla* (after *madhyakāla*).

Example :

Suppose the given time, *iṣṭaghaṭī* = 2 gh. after *sparśakāla*

grāsa = 16|48 *aṅgulas*

sparśa sthiti = $4|39$ *ghaṭīs*

grāsa at 2 gh. after *sparśakāla* $= \left(\dfrac{2 \times 16|48}{4|39}\right) + 1|15$ *aṅgulas*

$= 8|28$ *aṅgulas*

Śloka 9 : This *śloka* explains the method of finding *āyanavalanam*.

(i) In the case of a lunar eclipse, consider the true longitude of the Sun at the *parvānta*. Subtract 90° from it. This gives *tribhoṇa* Ravi.

In the case of a solar eclipse add 90° to the true position of the Sun at the *darśānta* (conjunction).

(ii) Add *ayanāṃśa* to (i) to get *sāyana tribhoṇa* Ravi. Find *bhuja* of this.

(iii) Considering 7, 5, 1 as *carakhaṇḍas*, find *gatakhaṇḍa*, *bhogyakhaṇḍa* and the remainder for the above result (as explained in *śloka* 5 of Chapter 2).

Then, *āyanavalanam* is given by

$$\bar{A}yanavalanam = \left[\frac{Bhogyakhaṇḍa \times \text{Remainder}}{30}\right] + gatakhaṇḍa$$

Example : (*Nirayaṇa*) Ravi at *parvānta* = $8^R\ 0^\circ\ 12'\ 16''$

Ayanāṃśa = $18^\circ\ 18'$

Sāyana tribhoṇa Ravi = $5^R\ 18^\circ\ 30'\ 16''$

Bhuja of *sāyana tribhoṇa* Ravi = 11° 29′ 44″

Gatakhaṇḍa = 0, *bhogyakhaṇḍa* = 7

and remainder = 11° 29′ 44″

$$\therefore \bar{A}yana\ valanam = \left[\frac{7 \times 11^\circ\ 29'\ 44''}{30^\circ}\right] + 0 \quad = 2|40\ \text{aṅgulas}$$

Since *tribhoṇa* Ravi is in the *uttaragola* (i.e., less than 6 R) the *valanam* is also in the *uttaragola.*

Notes : In Fig. 5.2 γSA is the ecliptic and γMB is the celestial equator and $\in$ is the obliquity of the ecliptic. The position of a celestial body is represented by S on the ecliptic.

Āyana valanam is the deflection of a point due to the obliquity of the ecliptic i.e., the angle subtended at the point by arc KP where K and P

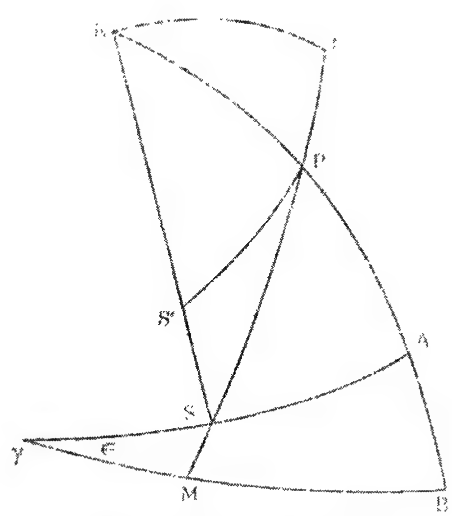

Fig. 5.2 *Āyanavalanam*

are respectively the poles of the ecliptic and the celestial equator.

In the figure, from spherical triangle *SKP*, we have

$$\frac{\sin v_1}{\sin \in} = \frac{\sin S\hat{K}P}{\sin SP}$$

But $S\hat{K}P = 90^\circ - \lambda$ and $SP = 90^\circ - \delta$ where λ and δ are respectivly the celestial longitude and declination of the body.

$$\therefore \qquad \sin v_1 = \frac{\sin \in \ \cos \lambda}{\cos \delta}$$

where v_1 is the *āyana valanam*.

Śloka 10 : Now, computation of the *akṣa valanam* is explained.

(i) Divide the mean *natakāla* by 5 to get the result in *rāśis* etc.

(ii) Taking the *bhuja* of (i) and using the *khaṇḍas* 7, 5, 1 (as explained in the previous *śloka*) find the *valanam*.

(iii) The *valanam*, obtained in (ii), is multiplied by the *palabhā* of the place and then divided by 5. This gives the (*spaṣṭa*) *akṣa valanam*.

This *akṣavalanam* is north or south according as the *nata* is eastern or western.

(iv) If the *āyana valanam* and the *akṣa valanam* are in the same direction, then take their sum (which will have the same direction). If these are in the opposite directions, then take their difference (whose direction will be that of the *valanam* with higher magnitude).

(v) Divide the above combined *valanam* by 6 which gives the *valanāṅghri*, in the above obtained direction, of the commencement of the eclipse.

Example : *Madhya nata* = $2|27$ (east). (i) Dividing by 5, we get $0^R\ 14°\ 42'\ 0''$. (ii) *Bhuja* = $14°\ 42'$. Using the *bhogya khaṇḍa* 7, we have $14°\ 42' \times 7/30 = 3|25$. (iii) *palabhā* = $5|45$ aṅg. Multiplying $3|25$ by $5|45$ and dividing by 5, we get $3|56$. This is (*spaṣṭa*) *akṣa valanam.* This is in the north direction since the *nata* is in the east. (iv) The (previously obtained) *āyana valanam* = $2|40$ north. (iv) Since both *āyana* and *akṣa valanams* are in the north (the same direction), adding them, we get the combined (*samskṛta*) *valanam* = $3|56 + 2|40 = 6|36$, north (v) Dividing $6|36$ by 6, we get $1|06$ north. This is the *valanāṅghri* (or *valana caraṇa*).

Śloka 11 : Now, determination of *grāsāṅghri* and *khagrāsāṅghri* is explained.

(First half of *Śloka* 11) :

(i) Multiply *grāsamāna* by 60 and divide by *mānaikya khaṇḍa* (sum of the diameters of the *chādya* and the *chādaka*).

Take the square root of the above result. This gives the *grāsāṅghri* in *aṅg.*

(ii) Add $1|30$ *aṅg.* to the *khagrāsa* to get *khagrāsāṅghri.*

Example : *Grāsa* = $16|48$ *aṅgulas* and *Mānaikyakhaṇḍa* = $19|38$ *aṅgulas.*

(i) Therefore, *Grāsāṅghri* = $\sqrt{\dfrac{16|48 \times 60}{19|38}}$ *aṅg.*

$$= 7|9|55 \text{ aṅg.}$$

(ii) *Khagrāsa* = 5|41 *aṅgulas*

Adding 1|30 *aṅg*. to the *khagrāsa*, we get *khagrāsāṅghri* = 7|11 *aṅgulas*.

(Second half of *Śloka* 11) :

Draw a circle and mark the north, east, south and west directions. Divide this circle into 32 parts (through the centre). If the (combined) valana is south, then starting from the direction of the *śara* proceed in the clockwise direction and measure the amount of the *valanāṅghri*. This gives the middle of the eclipse.

On the otherhand, if the *valana* is north, then proceed in the anticlockwise direction and measure the amount of the *valanāṅghri*. Similarly, in the opposite direction the *khagrāsa* or *bimba śeṣa* takes place.

Śloka 12 : Now, the determination of the directions of the beginning and the end of an eclipse (and of the totality) is explained.

From the middle of the eclipse, in the eastern direction the amount of the *grāsāṅghri* is measured to obtain the direction of the *sparśa* (beginning) of the eclipse. The same in the western direction gives the direction of the end (*mokṣa*) of the eclipse in the case of a lunar eclipse. In the case of a solar eclipse the opposite of the said directions must be taken. The same is the case for a total eclipse (*khagrāsa*) to obtain its beginning (*sammīlana*) and the end (*unmīlanam*) starting with *khagrāsa* point.

CHAPTER 6

SŪRYAGRAHAṆĀDHIKĀRAḤ

(Computation of Solar Eclipse)

***Ślokas* 1 and 2** : These *ślokas* explain the method of finding *lambana*. It is as follows :

(i) Find the *sāyana lagna* at the *kṛṣṇa parvānta* (i.e. *darśānta*). Subtract 3 *rāśis* from it. The result is called *sāyana vitribha lagna* (or *tribhoṇa lagna*).

(ii) Find the *krānti* (declination) of the above *sāyana vitribha lagna*. Add *akṣāṃśa* to (or subtract from) the *krānti*. This result is called *natāṃśa*.

i.e., *natāṃśa* = *krānti* ± *akṣāṃśa*

or *natāṃśa* = $\delta - \phi$

where δ = declination and ϕ = latitude of the place.

(iii) Divide the *natāṃśa* by 22. Square the resulting quotient.

(iv) If the square obtained in step (iii) is less than 2, then add 12 to it. This result is called *hāra*.

(v) On the otherhand, if the result of step (iii) is greater than 2, then subtract 2 from it. Divide the difference by 2. Add this to the square obtained in step (iii) and add 12 to the result. This is called *hāra*.

$$\text{i.e.,}\quad hāra = \left(\frac{natāṃśa}{22}\right)^2 + \left[\frac{\left(\frac{natāṃśa}{22}\right)^2 - 2}{2}\right] + 12$$

To find *lambana* (effect of parallax on the longitude] :

(i) Consider the difference between *sāyana vitribhalagna* and the Sun. Divide this difference by 10.

(ii) Multiply the difference between the above result and 14 by the result of step (i).

(iii) Divide the result of (ii) by *hāra*. The resulting quotient is called *lambana*.

$$\text{i.e., if}\quad x = \left(\frac{vitribhalagna - the\ Sun}{10}\right)$$

$$\text{then,}\quad lambana = \frac{(14 - x)x}{\text{hāra}}$$

Note : (i) In x, its *bhuja* must be taken;

(ii) If *vitribha lagna* > the Sun, add *lambana* to *darśānta* to get *spaṣṭa darśānta* (corrected *darśānta*).

Remark : *Lambana* is the effect of parallax on the longitude and *nati* is that on the latitude of the Moon.

Example : *Vikrama samvat* 1677, *Śālivāhana śaka* 1532. *Mārgaśira kṛṣṇa amāvāsyā*, Wednesday, *Cakra* = 8, *Varṣagaṇa* = 90 and *Ahargaṇa* = 1005.

This corresponds to December 15, 1610 (G), Wednesday

At the mean sunrise, we have

$$\text{Mean Sun} = 8^R\, 5°\, 39'\, 25'', \quad \text{Mean Moon} = 8^R\, 1°\, 10'\, 33''$$

$$\text{Rāhu} = 2^R\, 11°\, 41'\, 59'' \quad \text{and} \quad \textit{Candrocca} = 8^R\, 17°\, 7'\, 21''$$

According to that year's *pañcāṅga* the end of *amāvāsya tithi* is at $12|36$ *ghaṭīs* (after the sunrise). At this instant the true positions of the heavenly bodies are as follows.

$$\text{True Sun} = 8^R\, 5°\, 25'\, 57'' \equiv S, \quad \text{True Moon} = 8^R\, 5°\, 20'\, 41'' \equiv M$$

$$\textit{Candrocca} = 8^R\, 17°\, 8'\, 45'' \quad \text{and} \quad \text{Rāhu} = 2^R\, 11°\, 41'\, 19''$$

True daily motion of the Sun, $DS = 61'15''$

True daily motion of the Moon, $DM = 726'\, 30''$

Therefore, the instant of *parvānta,* t_p is given by

$$t_p = \left[t_o + \frac{S - M}{DM - DS} \times 60 \right] gh.$$

where $t_o = 12|36$ *ghaṭīs* (after the sunrise)

$$\therefore \quad t_p = \left[12|36 + \frac{5'16''}{726'\, 30'' - 61'\, 15''} \times 60 \right] gh.$$

$$= 12|36 + 0|28 \ \textit{ghaṭīs} \ = \mathbf{13|4} \ \textit{ghaṭīs}$$

i.e., $0^{gh}\, 28^{vig}$ after the *iṣṭakāla,* $12|36$ *gh.* Now, at this instant of *parvānta* (or *darśānta*).

True Sun = $8^R\ 5°\ 26'\ 25''$, True Moon = $8^R\ 5°\ 26'\ 20''$

Rāhu = $2^R\ 11°\ 41'\ 18''$ and

Virāhvarka = Sun – Rāhu = $5^R\ 23°\ 45'\ 7''$

Now, *darśānta* = $13|4$ *ghaṭīs* ; *lagna* at *darśānta* = $11^R\ 2°\ 46'\ 17''$

Vitribha lagna = *lagna* – 3 *rāśis*

$= 11^R\ 2°\ 46'\ 17'' - 3^R = 8^R\ 2°\ 46'\ 17''$

Krānti of *Vitribhalagna* $\delta = 23°\ 38'\ 10''$ (south)

akṣāṃśa $\phi = 25°\ 26'\ 42''$ (north) for *Kāśī*

∴ *natāṃśa* = *krānti* – *akṣāṃśa* $\equiv \delta - \phi$

$$= -23°\ 38'\ 10'' - 25°\ 26'\ 42'' = -49°\ 4'\ 52''$$

i.e., $49°\ 4'\ 52''$ (south)

Now, $$\left(\frac{nat\bar{a}\d{m}\acute{s}a}{22}\right)^2 = \left(\frac{49|4|52}{22}\right)^2 = (2|13|51)^2 = 4|58|37$$

Since $\left(\frac{nat\bar{a}\d{m}\acute{s}a}{22}\right)^2 = 4|58|37 > 2$, subtracting 2 from the square and dividing this by 2, we get $\frac{4|58|37 - 2}{2} = 1|29|18$

$$hāra = \left(\frac{natāṃśa}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{natāṃśa}{22}\right)^2 - 2\right] + 12$$

$$= (4|58|37 + 1|29|18 + 12)\ gh. \approx 6|27 + 12\ ghaṭīs = 18|27\ ghaṭīs$$

To find *lambana* :

Vitribha lagna = $8^R\ 2°\ 46'\ 17''$

The Sun - *vitribha lagna* = $2°\ 40'\ 8''$

Let $x = \dfrac{2°\ 40'\ 8''}{10} = 0|16$

Now, we have

$$lambana = \frac{(14 - x)x}{hāra} = \frac{(14 - 0|16)\,0|16}{18|27} = 0|11\ ghaṭīs$$

Since *vitribha lagna* < the Sun, subtract *lambana* from *darśānta* to get the *spaṣṭa darśānta.*

i.e., *spaṣṭa darśānta* = $13^{gh.}\ 04^{vig} - 0^{gh.}\ 11^{vig} = \mathbf{12^{gh.}\ 53^{vig}}$

***Śloka* 3** : This *śloka* explains the method of finding the *lambana* corrected *vyagu* and the *lambana* corrected *natāmśa*. It is as follows.

(i) Multiply *lambana* by 13. The resulting product will be in *kalās.*

(ii) The above result is added to or subtracted from *vyagu* (Sun – *Rāhu*) depending on whether the *lambana* is additive or subtractive respectively.

(iii) Find *śara* of the above *lambana* corrected *vyagu.*

(iv) Multiply *lambana* by 6.

(v) If *lambana* is negative, subtract the result of step (iv) from *vitribha lagna*. If *lambana* is positive, add the result of step (iv) to *vitribha lagna*.

(vi) Find the *krānti* (declination) of the *lambana* corrected *lagna*.

(vii) Now, the *lambana* corrected *natāṁśa* is obtained from the declination δ of the corrected *lagna* $\pm$ *akṣāṁśa* i.e., $\delta - \phi$

where δ is the declination of the corrected *lagna* and ϕ is the latitude of the place.

Example : We have

vitribha lagna = $8^R\ 2^\circ\ 46'\ 17''$, *lambana* = $-0|11$ *ghaṭīs* and

vyagu = $5^R\ 23^\circ\ 45'\ 07''$

$\therefore$ (i) *lambana* corrected *vyagu* = *vyagu* $-\ 13 \times$ *lambana*

$$= 5^R\ 23^\circ\ 45'\ 07'' - (13 \times 0|11) = 5^R\ 23^\circ\ 45'\ 07'' - 2'\ 23''$$

$$= 5^R\ 23^\circ\ 42'\ 44''$$

(ii) *Śara* for the *lambana* corrected *vyagu*

$$= \frac{11}{7} \times (\textit{bhuja of corrected vyagu}) = \frac{11}{7} \times (6^\circ\ 17'\ 16'') = 9|53$$

aṅgulas

Since *vyagu* $< 180^\circ$, *śara* is positive.

Now, $6 \times$ *lambana* $= 6 \times 0|11 = 1^\circ\ 6'$

Since *lambana* is negative, subtract $6 \times lambana$ from *vitribha lagna* to get the corrected *vitribha lagna*.

i.e., corrected *vitribha lagna* = $vitribha\ lagna - 6 \times lambana$

$$= 8^R\ 2^\circ\ 46'\ 17'' - 1^\circ\ 06' = 8^R\ 1^\circ\ 40'\ 17''$$

The *krānti* of the corrected *lagna* = $23^\circ\ 34'\ 35''$ (south)

(obtained as explained in Chapter 4)

Akṣāmśa = $25^\circ\ 26'\ 42''$ (north) for Kāśī

∴ corrected *natāṃśa* = *krānti* of corrected *lagna* – *akṣāṃśa*

$$= -23^\circ\ 34'\ 35'' - 25^\circ\ 26'\ 42'' = 49^\circ\ 01'\ 17''\ \text{(south)}$$

***Śloka* 4** : The method of determining *nati* as well as the *sthiti* is explained in this *śloka* as follows :

(i) Divide the *lambana* corrected *natāṃśa* by 10.

(ii) Subtract the above result from 18.

(iii) Multiply the results of step (i) and step (ii). The product will be in *kalās*.

(iv) Subtract the result obtained in step (iii) from $6^\circ\ 18'$.

(v) Divide the result of step (iii) by that of step (iv). The result obtained is called *nati*. Thus if *lambana* corrected *natāṃśa* is denoted by *ln*, then

$$nati = \frac{\left(18 - \frac{ln}{10}\right)\frac{ln}{10}}{6^\circ\ 18' - \left[\left(18 - \frac{ln}{10}\right)\frac{ln}{10}\right]}$$

(vi) Using the above *nati*, we can get corrected *śara* (or *spaṣṭa śara*) by adding *śara* to (or subtracting from) *nati.*

i.e., *spaṣṭa śara* = *nati* ± *śara*

Note : Here the *śara* of the *lambana* corrected *vyagu* is to be considered.

Using the *spaṣṭa śara* find *mānaikyakhaṇḍa, grāsa* and *khagrāsa* or *khacchanna.*

Example : We have

lambana corrected *natāṃśa* $ln = 49^\circ\ 1'\ 17''$

$$nati = \frac{\left(18 - \frac{ln}{10}\right)\frac{ln}{10}}{6^\circ\ 18' - \left[\left(18 - \frac{ln}{10}\right)\frac{ln}{10}\right]} = -12\ |16$$

∴ *Spaṣṭa Śara* = $-12|16 + 9|53$ *aṅgulas* = $-2|23$ *aṅgulas.*

(**Note** : *nati* is –ve since *natāṃśa* is south).

To find *sthiti* :

The method of finding *sthiti* is the same as that explained in Chapter 5 (computation of lunar eclipse). We have

Spaṣṭa Śara, s = $2|23$ *aṅgulas* (south)

Sun's diamater, $d_s = 11|8$ *aṅgulas*

Moon's diameter, $d_m = 9|49$ *aṅgulas*

Mānaikyakhaṇḍam, $m = 10|28.5$ *aṅgulas*

grāsa, $g = 8|6$ *aṅgulas* (approximately)

$$\therefore \ sthiti = \frac{5}{6} \frac{[(s+m) \times 10 \times g]^{1/2}}{d_m} \ ghat\bar{\imath}s \ = 2|44 \ \boldsymbol{ghat\bar{\imath}s}$$

(*Śloka* 5 in Chapter 5).

***Śloka* 5** : This *śloka* explains the method of finding the *sparśa* and *mokṣa kālas* of the eclipse. It is as follows.

(i) Multiply *sthiti* by 6. The result will be in degrees, minutes, seconds.

(ii) Subtract the result of step (i) from the *parvānta tribhoṇa lagna* (*PTL*) to get the *sparśakāla tribhoṇa lagna* (*STL*) and adding the same result to the *tribhoṇa lagna* (*PTL*) we get the *mokṣakāla tribhoṇa lagna* (*MTL*).

(iii) Find *lambana* using the *sparśakāla tribhoṇa lagna* and the *mokṣa kāla tribhoṇa lagna*. These are called *sparśakāla lambana* and *mokṣakāla lambana* respectively.

(iv) The *sthiti* is added to and subtracted from the *sparśa lambana* and the *mokṣa lambana* to get the corrected *sparśa* and *mokṣa sthitis* respectively.

(v) Subtract the corrected *sparśa sthiti* from *darśānta*.This gives the *sparśa kāla* in *ghaṭīs*.

(vi) Add *mokṣa sthiti* to *darśānta*. This gives the *mokṣakāla* in *ghaṭīs*.

Example : We have the *sthiti* = $2|44$ *ghaṭīs*

(Śāyana) vitribha (or *tribhoṇa*) *lagna* = $8^R\ 2°\ 46'\ 17''$

Now, $6 \times$ *sthiti* = $6 \times (2|44) = 16°\ 24'$

(i) *Spraśakāla tribhoṇa lagna* $= 8^R\ 2°\ 46'\ 17'' - 16°\ 24'$

$= 7^R\ 16°\ 22'\ 17''$

(ii) *Mokṣa kāla tribhoṇa lagna* $= 8^R\ 2°\ 46'\ 17'' + 16°\ 24'$

$= 8^R\ 19°\ 10'\ 17''$

To find *sparśa lambana* :

Declination of the *sparśakāla tribhoṇa lagna*, $\delta = -21°\ 24'\ 39''$

Akṣāṃśa $\phi = 25°\ 26'\ 42''$

Natāṃśa = $\delta - \phi = 46°\ 51'\ 21''$ (south)

$$\text{Now, } \textit{Hāra} = \left(\frac{\textit{natā ṃ śa}}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{\textit{natāṃśa}}{22}\right)^2 - 2\right] + 12$$

$$= \left(\frac{46|51|21}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{46|51|21}{22}\right)^2 - 2\right] + 12 = 17|48$$

Ravi at *parvānta* = $8^R\ 5°\ 26'\ 25''$

True motion of Ravi = $61'\ 15''$

Sthiti = $2^{gh}\ 44^{vg}$

Motion of Ravi in $2^{gh}\ 44^{vg} = 2'\ 47''$

$\therefore$ Ravi at *sparśa kāla* = $8^R\ 5°\ 26'\ 25'' - 2'\ 47'' = 8^R\ 5°\ 23'\ 38''$

Sparśakāla vitribha Lagna = $7^R\ 16°\ 22'\ 17''$

Ravi – *Lagna* = $19°\ 01'\ 21''$

Now,

$$\frac{1}{10}^{th} \text{ of } Bhuja \text{ of } (\text{Ravi} - Lagna) = 1°\ 54' \text{ and } 14° - 1°\ 54' = 12°\ 6'$$

Sparśa lambana = $\dfrac{12°\ 6' \times 1°\ 54''}{H\bar{a}ra} = \dfrac{22|49}{17|48} = 1^{gh.}\ 17^{vg.}$
(Numerical Value)

i.e., *Sparśa lambana* = $-\ 1^{gh}\ 17^{vg}$

To find *mokṣa lambana* :

Mokṣakāla vitribha Lagna = $8^R\ 19°\ 10'\ 17''$

Declination of the above = $-23°\ 42'\ 28'' \equiv \delta$
(Numerical value)

Akṣāṃśa = $+\ 25°\ 26'\ 42'' \equiv \phi$

Natāṃśa = $\delta - \phi = -\ 49^\circ\ 9'\ 10''$

Hāra = $18|28$ (obtained as explained earlier)

Ravi at *Mokṣakāla* = $8^R\ 5^\circ\ 26'\ 25'' + 2'\ 47'' = 8^R\ 5^\circ\ 29'\ 12''$

where $2'\ 47''$ is the motion of Ravi in $2^{gh}\ 44^{vg}$ *(sthiti).*

Now, Ravi – *lagna* = $0^R\ 13^\circ\ 41'\ 5''$

$\frac{1}{10}^{th}$ of *Bhuja* of (Ravi – *lagna*) = $1|22$

and $14 - 1|22 = 12|38$

Now, $\dfrac{12|38 \times 1|22}{Hāra} = \dfrac{12|38 \times 1|22}{18|28} = 0^{gh}\ 56^{vig}$

i.e., *Mokṣa lambana* = $0^{gh}\ 56^{vig}$

To find *sparśa* and *mokṣa kālas* :

We have *darśānta* = $13^{gh}\ 04^{vg}$ and *sthiti* = $2^{gh}\ 44^{vig}$

$\therefore$ *darśānta – sthiti* = $13^{gh}\ 04^{vig} - 2^{gh}\ 44^{vig} = 10^{gh}\ 20^{vig}$

Sparśa lambana = $-1^{gh}\ 17^{vig}$

Now, *sparśakāla* = $10^{gh}\ 20^{vig} - 1^{gh}\ 17^{vig} = 9^{gh}\ 03^{vig}$

We have

darśānta + *sthiti* = $13^{gh}\ 04^{vig} + 2^{gh}\ 44^{vig} = 15^{gh}\ 48^{vig}$

Mokṣa lambana = $0^{gh}\ 56^{vig}$

$\therefore$ *Mokṣakāla* = $15^{gh}\ 48^{vig} + 0^{gh}\ 56^{vig} = 16^{gh}\ 44^{vig}$

Summary of the eclipse :

Beginning of the eclipse: $9^{gh}\ 03^{vig}$

Middle of the eclipse: $13^{gh}\ 04^{vig}$

End of the eclipse : $16^{gh}\ 44^{vig}$

***Śloka* 6** : This *śloka* explains the method of finding *sammīlanakāla* and *unmīlanakāla* (in the case of a total eclipse). The colour of the eclipse is also explained.

(i) To find *sammīlana* and *unmīlana kālas* :

Consider *marda* in the place of *sthiti* and proceed as explained previously to get *sammīlana kāla* and *unmīlana kāla.*

(ii) Colour of the eclipse :

If the *grāsa* of the lunar eclipse is small (*alpagrāsa,* less than $1/2$) then the colour of the eclipse is smoke colour (*dhūmra varṇa*). If the *grāsa* of the lunar eclipse is half (i.e., *ardhagrāsa*) then the colour of the eclipse is black (*kṛṣṇa varṇa*) and the colour of the eclipse will be brown (*piṅgalavarṇa*) if the *grāsa* is full (*sampūrṇa grāsa*).

In the case of a solar eclipse whether the *grāsa* is small or half or full the solar eclipse will be only of black colour. Further, if the *grāsa* of a total eclipse is less than one *aṅgula*, the eclipse should not be predicted since the small eclipsed portion cannot be recognised due to the powerful solar rays.

***Śloka* 7** : This *śloka* explains the method of finding *grāsa* at a given time (*iṣṭakāla*)

(1) Multiply the *iṣṭaghaṭī* (i.e., given time in *ghaṭīs*) by $2 \times$ *grāsa.*

(2) Divide the above product by the difference of *sparśa* and *mokṣa ghaṭīs.*

(3) Add $\frac{1}{2}$ *aṅgula* to the result obtained in step (2). This gives the *grāsa* at the *iṣṭakāla.*

Example : Let *iṣṭaghaṭī* = 1 *ghaṭī* and *grāsa* = $8|6$ *aṅgulas*

(1) Now, 2 $\times$ *grāsa* $\times$ *iṣṭaghaṭī* = $2 \times 1 \times 8|6 = 16|12$

(2) *Spaśakāla* = $9^{gh}\ 03^{vig}$ and *Mokṣakāla* = $16^{gh}\ 44^{vig}$

The difference = $7^{gh}\ 41^{vig}$ (i.e., duration of the eclipse)

(3) We have

Grāsa at the given the time

$$\frac{16|12}{7|41} + \frac{1}{2} = 2|6 + 0|30 \qquad [\because \tfrac{1}{2} \text{ } a\dot{n}gula = 0|30 \text{ } a\dot{n}gula]$$

$$= 2|36 \ a\dot{n}gulas = 2^{ang}\ \ 36^{p.ang}$$

(Note : 1 *aṅgula* = 60 *pratyaṅgulas).*

To find *valanam* and *parilekhā* :

We have

lambana corrected *darśānta* = $12^{gh}\ 53^{vig}$

The Sun at *parvānta* = $8^{R}\ 5°\ 26'\ 14''$

Adding 3 *rāśis* we get $11^{R}\ 5°\ 26'\ 14''$

Adding *ayanāmśa* $18°\ 08'$ to the above, we get $11^{R}\ 23°\ 34'\ 14''$

Now, as explained in Ch. 5, *Ślokas* 9 and 10, we have

(i) *Ayana valanam* = $1|30$ (south) and *dinārdham* = $13^{gh}\ 3^{vig}$

nata = $0|10$, *akṣa valanam* = $0|14$ (north) and *palabhā* = $5|45$ *aṅgulas*

$$\therefore \textit{corrected akṣa valanam} = \frac{5|45 \times 0|14}{5} = \frac{1|20}{5} = 0|16 \text{ (north)}$$

Resultant of the *two valanas* :

$$1|30 - 0|16 = 1|14 \text{ (south)}$$

$$\text{Now, } \textit{valanāṅghri} = \frac{1|14}{6} = 0|12 \text{ (south)}$$

grāsa = $8|6$ *aṅgulas*

(ii) *Parilekhā* $= \left[\dfrac{\textit{grāsa} \times 60}{\textit{mānaikyakhaṇḍa}}\right]^{1/2}$

$$= \left[\frac{8|6 \times 60}{10|28}\right]^{1/2} = (46|26)^{1/2} = 6|49$$

(also called *channāṅghri*).

CHAPTER 7

MĀSAGAṆĀDHIKĀRAḤ

(Accumulated Lunar Months)

Śloka 1 : Now, computations of lunar and solar eclipses are presented, with *māsagaṇa* (heap of lunar months) by obtaining the true positions of the Sun, *vyagu, tithi, bimba* (diameters) and *grāsa* using simple and ingenuous techniques.

Śloka 2 : This *śloka* gives the *kṣepaka* of the Sun, *vyagu*, *vṛtta* (i.e., *candrakendra*) and *vārādika* of *tithi* as follows :

Sun	$0^R\ 4°\ 21'$
Vyagu	$11^R\ 07°\ 18'$
Candrakendra	$0^R\ 14°\ 51'$
Tithi (vārādika)	$2^d\ 48^{gh}\ 45^{vig}$

The above values are the mean positions at the mean fullmoon following the epochal date [March 19, 1520 (J)] i.e. on April 2, 1520 (J), Monday at $48^{gh}\ 47^{vig}$.

Remark : In the chapter *Madhyamādhikāra* the epochal mean positions (*kṣepakas*) are as follows :

Mean Sun : $11^R\ 19°\ 41'$, Mean Moon : $11^R\ 19°\ 06'$

Moon's apogee (*Mandocca*) : $5^R\ 17°\ 33'$ and Rāhu : $0^R\ 27°\ 38'$

$\therefore$ *Vipāta* = Mean Sun – Rāhu = $10^R 22°06'$,

Candra kendra = Mean Moon – *Mandocca* = $6^R 1°33'$

Vārādika = 2^d at the mean sunrise at Ujjayinī.

These are the mean positions at the mean sunrise on *Śaka* 1442 *Caitra Pratipat* (March 19, 1520, Monday). Now, since the mean sunrise is not the time of the *darśānta* (*amāvāsyā*), we shall find out the mean instant of the conjunction of the Sun and the Moon.

The difference between the mean Sun and the mean Moon = $11^R\, 19°\, 41' - 11^R\, 19°\, 06' = 35' = 2100''$. The difference in the mean daily motions of the Moon and the Sun = $790'\, 35'' - 59'\, 08'' = 731'\, 27'' = 43887''$. Therefore, the time required (after sunrise) for the mean conjunction is

$$\frac{2100}{43887} \times 60 \approx 2\, gh.\, 52\, vig.$$

$\therefore$ *Vārādika* of Amāvāsyā = $2^d\, 2^{gh}\, 52^{vig}$

The motion of the Sun in $2\, gh.\, 52\, vig.$ is $\dfrac{2\, gh.\, 52\, vig.}{60} \times 59'\, 08'' \approx 3'$

Thus at the mean conjunction of the Moon and the Sun (i.e., at the instant of the New Moon) we have

the mean Sun = the mean Moon = $11^R 19°44'$

the Moon's apogee (*mandocca*) = $5^R 17°33'$

Vṛttam = Moon's *mandakendra*

= Mean Moon – Moon's *mandocca* = $6^R 02° 11'$.

Vipāta (Vyagu) = Mean Sun – Rāhu = $10^R 22° 09'$.

Pākṣika Cālanam **: (Motion of the Sun etc. in the course of a half lunar month) :**

The length of a mean lunar month = $29^d.53059$.

$\therefore$ Half lunar month (*pakṣa*) = $14^d.765295$

The mean motions of the bodies in a *pakṣa* are

(i) Sun : $0^R\ 14°\ 33'$

(ii) Moon : $6^R\ 14°\ 33'$

(iii) *Vṛtta* (*mandakendra*) : $6^R\ 12°\ 54'$

(i.e., Moon's motion – *Mandocca*'s motion = $6^R\ 14°\ 33' - 1°\ 39'$

= $6^R\ 12°\ 54'$)

(iv) *Vipāta's* (i.e., Sun – Rāhu) = $0^R\ 15°\ 20'$ which can be obtained as follows:

Sun's mean daily motion : $59'\ 08''$

Rāhu's mean daily motion : $-3'\ 11''$

$\therefore$ *Vipāta*'s daily motion : $62'\ 19''$ $[= 59'\ 08' - (-3'\ 11'')]$

Hence *vipāta*'s *pākṣika gati*

$$= \frac{62'\ 19'' \times 14^d.765295}{60} \text{ degrees } = 0^R\ 15°\ 20'$$

(v) *Vārādi pākṣika* for *tithi :*

We have *pakṣa* = 14.765295 days. Dividing the number of days by 7 and taking the remainder, we get $0^d\ 45^g\ 55^{vig}$.

Adding the *pākṣika* motions to the relevant *kṣepakas* (epochal positions) we get, at the succeeding full moon: Mean Sun = $0^R 4°21'$,

Vipāta (Vyagu) = $11^R 7°29'$, *Candra kendra* (≡ *Vṛttam*) = $0^R 14°51'$,

Vārādika of *tithi* = $2^d 48^{gh} 55^{vig}$ (with small differences!).

***Śloka* 3** : This *śloka* gives the *dhruvaka* of the mean Sun, *vyagu*, *candrakendra* and *vāra* etc. of *tithi* as follows.

Sun	$0^R\ 1°\ 40'$
Vyagu	$7^R\ 1°\ 12'$
Candrakendra	$9^R\ 1°\ 16'$
Tithi	$5^d\ 9^{gh}\ 36^{vig}$

Dhruvaka is the residual motion in a *cakra* after removing completed revolutions.

***Śloka* 4** : This *śloka* explains the method of finding positions of the Sun and the *vyagu* using *māsagaṇa*. It is as given below :

(i) Find the *māsagaṇa* for the given date.

(ii) Divide the *māsagaṇa* by 67 and multiply it by 2.

(iii) Subtract the result obtained in step (ii) from the *māsagaṇa*. This gives Ravi in *rāśis* etc.

(iv) Take the *māsagaṇa* as *rāśis* (for *Vyagu*). Divide the *māsagaṇa* by 3. Subtract this from the *māsagaṇa* to get the result in *aṃśas*.

(v) Divide the *māsagaṇa* by 4. The result will be in *kalās*.

(vi) The results of steps (iv) and (v) give the *amśas* and *kalās* of *vyagu*.

Example : *Samvat* = 1669, *Śaka* = 1534

Kārtika Śukla Paurṇimā, Thursday i.e. Nov.8, 1612(G).

For the given date, *Cakra* is 8 and *māsagaṇa* is 57.

The *māsagaṇa* is arrived at as follows :

(i) *Śālivāhana Śaka Varṣa* – 1442 = 1534 – 1442

i.e., elapsed years from the epochal year = 92

(ii) *Cakra* = Quotient of $92/11 = 8$

(iii) *Śeṣa* (remainder) = 4

(iv) *Śeṣa* $\times\ 12 = 48$ months

(v) Months elapsed till the beginning of the given month (i.e., *Kārtika*) = 7

(i.e., from *Caitra* to *Āśvayuja*)

(vi) Adding results of (iv) and (v), we get 48 + 7 = 55

(vii) *Adhikamāsas* = 2

(viii) Therefore the total elapsed

Māsagaṇa = 48 + 7 + 2 = 57

To find Ravi :

(i) *Māsagaṇa* $\times\ 2|67\ =\ 114|67$ *rāśis* etc. = $1^R\ 21°\ 2'\ 41''$

(ii) Ravi = *Māsagaṇa* – item (i)

$$= 57^R - 1^R\ 21°\ 2'\ 41'' = 55^R\ 8°\ 57'\ 19''$$

Removing the multiples of 12 (i.e., 48), we get

Ravi = $7^R\ 8°\ 57'\ 19''$

To find *Vyagu* :

(i) *Māsagaṇa* = 57, ∴ *Rāśis* = 57 i.e. 9^R (removing 48^R)

(ii) Dividing the *māsagaṇa* by 3, quotient = 19

(iii) Dividing the *māsagaṇa* by 4, we get 14.25 *kalās* i.e., 14 *kalās* and 15 *vikalās*.

(iv) *Māsagaṇa* – item (ii) = $57° - 19° = 38°$ (in rāśis)

(v) *Vyagu* = item (i) + item (iv) + item (iii)

$$= 9^R 38° 14' 15'' = 10^R 8° 14' 15''$$

***Śloka* 5** : Now, the method of finding the *vṛtta* (i.e., moon's *mandakendra*, anomaly) and *vārādi* (weekday etc.) of the *tithi* is explained.

(i) Divide *māsagaṇa* by 14.

(ii) Removing the multiples of 14, consider the remainder and divide it by 7.

(iii) Subtract the result of (ii) from the *remainder*.

(iv) Add $\frac{1}{10}^{th}$ of the *māsagaṇa* (in degrees) to item (iii).

This gives the *vṛttam* (this is to be corrected as explained in the next *śloka*).

Example : *Māsagaṇa* = 57

(i) Dividing *māsagaṇa* by 14, the remainder is 1 considered as *rāśis*.

(ii) Remainder/7 = 1/7 *rāśi* = $0^R\ 4°\ 17'\ 08''$

(iii) Remainder − Remainder/7

$$= 1^R - 0^R\ 4°\ 17'\ 08'' = 0^R\ 25°\ 42'\ 52''$$

(iv) *Māsagaṇa*/10 + item (iii)

$$= 5°\ 42' + 0^R\ 25°\ 42'\ 52'' = 1^R\ 1°\ 24'\ 52''$$

Thus, *Vṛttam* = $1^R\ 1°\ 24'\ 52''$

(this has to be further corrected with *dhṛuva* and *kṣepaka*, explained in the next *śloka*).

To find the *vārādi* of *tithi* :

(i) Divide the *māsagaṇa* by 14 and consider the remainder.

(ii) Add $\frac{1}{2}$ of the remainder to itself.

(iii) Multiply the *māsagaṇa* by 10.

(iv) Divide the product by 327.

(v) Add the result of (iv) to (ii).

This gives the *vārādika* (weekday etc.) of the *tithi*.

Example : *Māsagaṇa* = 57

(i) *Māsagana* /14 : Quotient = 4, Remainder = 1.

(ii) Remainder + Remainder/2

$$= \left(1 + \frac{1}{2}\right)^d = 1^d\ \ 30^{gh}$$

(iii) *Māsagaṇa* $\times$ 10 = $57 \times 10 = 570$

(iv) Dividing (iii) by 327, we get $1^{d}\ 44^{gh.}\ 35^{vig.}$

(v) Adding (ii) and (iv), we get

$$1^{d}\,30^{gh}\cdot + 1^{d}\,44^{gh}\cdot\,35^{vig.} = 3^{d}\ 14^{g}\ 35^{vig.}$$

Thus, the *vārādik*a (weekday etc.) of the *tithi*

$$= 3^{d}\ 14^{gh}\ 35^{vig}$$

(This has to be further corrected with *dhruva* and *kṣepaka* as explained in the next *śloka*).

***Śloka* 6** : Here, corrections with *dhruvaka* and *kṣepaka* are explained.

(i) In the case of Ravi, subtract (*cakra* $\times$ *dhruvaka*) from and add *kṣepaka* to the *māsagaṇa* derived Ravi (obtained from *Śloka* 4).

(ii) In the case of *vipāta* (or *vyagu*), *vṛtta* (Moon's *mandakendra*) and *vārādika* (weekday etc.) of the *tithi* add (*cakra* $\times$ *dhruvaka*) and *kṣepaka* to the corresponding *māsagaṇa* derived results.

Example :Śaka 1534 Kārtika śukla paurṇimā, Thursday.

(i)	**Ravi** : *Māsagaṇa* derived Ravi	=	$7^{R}\ 8^{\circ}\ 57'\ 19''$
	Subtract *Dhruvaka* $\times$ *Cakra* :		$-\ 0^{R}\ 13^{\circ}\ 20'$
	We get		$6^{R}\ 25^{\circ}\ 37'\ 19''$
	Add *kṣepaka* :		$+\ 0^{R}\ 04^{\circ}\ 21'$

	Corrected Mean Ravi :	**6^R 29° 58′ 19″**		
(ii)	***Vyagu*** **:** *Māsagaṇa* derived *vyagu* =	10^R 08° 14′ 15″		
	Add (*Cakra* × *Dhruvaka*) :	+ 8^R 09° 36′		
	Add *kṣepaka* :	+ 11^R 07° 18′		
	Corrected *vyagu* :	5^R 25° 08′ 15″		
(iii)	***Vṛtta*** **(moon's *mandakendra*)** :			
	Māsagaṇa derived *vṛtta* =	1^R 01° 24′ 52″		
	Add (*Cakra* × *Dhruvaka*) :	+ 0^R 08° 48′		
	Add *kṣepaka* :	+ 0^R 14° 51′		
	Corrected *vṛtta* :	1^R 25° 03′ 52″		
(iv)	***Vārādika*** **of *tithi*** :			
	Māsagaṇa derived :	3^d	14^{gh}	35^{vig}
	Add (*Cakra* × *Dhruvaka*) :	+6	16	48
	Add *kṣepaka* :	+2	48	45
	Adding the above results:	12^d	20^{gh}	08^{vig}

Removing the nearest multiple of 7^d we get

Vārādika of *tithi* : $5^d\ 20^{gh}\ 08^{vig}$ (5^d indicates Thursday)

Śloka 7 : This *śloka* gives the motions in a *pakṣa* of the Sun, *vipāta*, *vṛtta* and *vārādika* of *tithi*. It is as given below.

The motion of the Sun = $0^R\ 14°\ 33'\ 0''$

The motion of the *vipāta* = $0^R\ 15°\ 20'\ 0''$

The motion of the *vṛtta* = $6^R\ 12°\ 54'\ 10''$

The motion of the *vārādika* of *tithi* = $0^d\ 45^g 55^{vig}$

The derivations of the above are shown in our explanation of *Śloka* 2.

Śloka 8 : The motions of Ravi, *vipāta*, *vṛtta* and *vārādika* of *tithi* in six months are given as below :

The motion of Ravi = $5^R\ 24°\ 38'$

The motion of *vipāta* = $6^R 4° 01'$

The motion of *vṛtta* = $5^R\ 4°\ 53'$

The motion of *dinādi* (vārādi) of *tithi* = $2^d\ 11^{gh}\ 01^{vig}$

Śloka 9 : Now, for the given (*iṣṭa*) *tithi*, finding of *dinādi* (weekday etc.) of the *tithi*, Ravi and *vṛtta* (Moon's *mandakendra*) is explained.

(i) From the *tithi* (before or after *pūrṇimānta* i.e., in the *śukla* or *kṛṣṇa pakṣa*) $1/64^{th}$ of it is subtracted. This gives the motion of the *tithi* in *vārādika* (weekday etc.)

i.e., Motion of *tithi* = $Tithi - Tithi/64$

(ii) Ravi's motion = $Tithi - Tithi/34$

(iii) *Vṛttam* motion = $[Tithi - Tithi/93] \times 13$

Derivation of the above expressions

Duration of a lunar month = $29^{d}\ 31^{gh}\ 50^{vig}$

Therefore, we have

(i) Civil days of the given *tithi*

$$= \frac{Tithi}{30} \times \left(29^{d}\ 31^{gh}\ 50^{vig}\right)$$

$$\approx \frac{Tithi}{30} \times \left(\frac{106310}{3600}\right)$$

$$= \frac{Tithi \times 10631}{10800}$$

$$= \frac{Tithi\,(10800 - 169)}{10800}$$

$$= Tithi - (169/10800)\ Tithi$$

$$\approx Tithi - Tithi/64$$

(ii) Ravi : Mean daily motion = $59'\,08''$

Civil days of *Tithi* = $Tithi - Tithi/64 = [\,(63|64) \times Tithi]$

∴ Motion of Ravi for the given *Tithi*

$$= (63/64) \times Tithi \times 59'\,08''$$

$$= \frac{63}{64} \times Tithi \times \left(\frac{3548}{3600}\right)^{\circ} = \frac{63}{64} \times (Tithi) \times \left(\frac{887}{900}\right) = \frac{55881}{57600} \times Tithi$$

$$= \frac{57600 - 1719}{57600} \times Tithi = \left(1 - \frac{1719}{57600}\right) \times Tithi$$

$$= \left(1 - \frac{1}{33.51}\right) \times Tithi \approx \left(1 - \frac{1}{34}\right) \times Tithi$$

(iii) *Vṛttam*, Moon's *mandakendra* :

We have

Moon's daily motion – *Mandocca*'s daily motion

$$= 790'\,35'' - 6'\,41'' = 783'54''$$

i.e., *Vṛatta*'s daily motion $= 783'\,54''$

Now, therefore the motion of *vṛtta* for 1 (one) *tithi* is given by $\frac{63}{64} \times 783'\,54''$

∴ For the required *tithi* (*iṣṭatithi*), the motion of *vṛtta* is

$$Tithi \times \frac{63}{64} \times 783'\,54'' = Tithi \times \frac{63}{64} \times \left[\frac{47034}{3600}\right]^{\circ}$$

$$= Tithi \times (12.8609) = Tithi\,\frac{92}{93} \times 13$$

$$= Tithi \times \frac{93-1}{93} \times 13 = Tithi \times \left(1 - \frac{1}{93}\right) \times 13$$

$$= \left[Tithi - \frac{Tithi}{93}\right] \times 13$$

***Śloka* 10** : Now, for finding the true Sun and the true *tithi*, the *mandakendras* of the Sun and the Moon will be obtained.

The *khaṇḍas* to find *mandakendraphalam* are as follows :

17, 16, 14, 12, 9, 5 and 2.

(i) Divide the *bhujāṃśa* of *vṛtta* by 13.

The resulting quotient gives the total number of elapsed or *gata khaṇḍas*.

(ii) Multiply the remainder obtained in step (i) by *eṣyakhaṇḍa* (the *khaṇḍa* to be covered) and divide the product by 13.

(iii) Add the above result to the sum of the *gatakhaṇḍas*. The result gives *mandakendraphalam* of Candra.

(iv) In the case of Ravi, considering the *mandakendra* of Ravi,follow the procedure of (i) to (iii) above. Then divide the result of (iii) by 2. Subtract $\frac{1}{6}^{th}$ of this result from itself. This gives the *Raviphalam*.

Example : *Vṛtta* = $1^R\ 25°\ 3'\ 52''$ (see example under Śloka 6).

Its *Bhuja* = $55°\ 3'\ 52''$

(i) Now, $\frac{Bhuja}{13^\circ} = \frac{55^\circ\ 3'\ 52''}{13^\circ} = 4 + \frac{3^\circ\ 3'\ 52''}{13^\circ}$

This implies that the number of *gatakhaṇḍas* is 4. They are 17, 16, 14 and 12. Their sum = 17 + 16 + 14 + 12 = 59

Eṣyakhaṇḍa (or *Bhogyakhaṇḍa*) = 9

(ii) $\frac{Bhogyakhanda \times \text{Remainder}}{13} = \frac{3^\circ\ 3'\ 52'' \times 9}{13} = 2^\circ\ 7'\ 17''$

(iii) Sum of *gatakhaṇḍas* + item (ii)

$= 59^\circ + 2^\circ\ 7'\ 17'' = \mathbf{61^\circ\ 7'\ 17''}$

Candra's *mandakendraphalam* (*vṛttaphalam*) = $+\mathbf{61^\circ\ 7'\ 17''}$ (additive)

Note :

(i) If *vṛttam* is within 6 *rāśi*s from *Meṣa* (i.e., if $0^\circ < vṛttam < 180^\circ$) then *mandakendraphalam* is additve.

If *vṛttam* is within 6 *rāśi*s from *Tulā*

i.e., if $(180^\circ < \text{vṛttam} < 360^\circ)$ then *mandakendraphalam* is negative.

(ii) The *mandakendraphalam* defined here is different from the *mandaphalam* (eqn. of centre) used in the *Śpaṣṭādhikāra*. However, the former is a multiple of the latter.

Now, Ravi = $6^R\ 29^\circ\ 58'\ 19''$

Mandocca of *Ravi* = $2^R\ 18^\circ = 78^\circ$ (from example under Śloka 6).

Ravikendra = *Mandocca* – Ravi

$$= 78^\circ - 6^R\ 29^\circ\ 58'\ 19'' \quad = 7^R\ 18^\circ\ 1'\ 41'' \text{ (adding } 12^R)$$

$$= 228^\circ\ 1'\ 41''$$

Bhuja of Ravikendra $= 228^\circ\ 1'\ 41'' - 180^\circ \quad = 48^\circ\ 1'\ 41''$

(i) $$\frac{Bhuja}{13^\circ} = \frac{48^\circ\ 1'\ 41''}{13^\circ} = 3 + \frac{9^\circ\ 1'\ 41''}{13^\circ}$$

This implies that the number of *gatakhaṇḍas* = 3

They are 17, 16 and 14.

Their sum = 17 + 16 + 14 = 47

Remainder = $9^\circ\ 1'\ 41''$

Eṣyakhaṇḍa = 12

(ii) Sum of the *gatakhaṇḍas* + $\dfrac{\textit{Eṣyakhaṇḍa} \times \text{Remainder}}{13}$

$$= 47 + \frac{12 \times 9^\circ\ 1'\ 41''}{13} \quad = 55^\circ\ 20'\ 0''$$

(iii) Take half of item (ii) :

$$\frac{55^\circ\ 20'\ 0''}{2} = 27^\circ\ 40'\ 0''$$

(iv) Subtract $\frac{1}{6}^{th}$ of (iii) from (iii) :

$$27° \, 40' \, 0'' - \frac{27° \, 40' \, 0''}{6} = 23° \, 03' \, 20''$$

Since Ravi = $6^R \, 29° \, 58' \, 19'' > 180°$ the above result is subtractive.

Therefore,

Ravi's *mandakendraphalam* (*vṛttaphalam*) = $-23° \, 03' \, 20''$

Note : Here also, the *"mandakendraphalam"* of Ravi is different from the *mandaphalam* (equation of centre) explained in *Spaṣṭādhikāra*.

Now, *Candraphalam* + *Raviphalam*

$= 61° \, 07' \, 17'' + (-23° \, 03' \, 20'')$

$= 38° \, 03' \, 57''$

This is the combination of the two *phalams* (*phala-dvaya-samskṛti*).

***Śloka* 11** : This *śloka* gives the method for finding *hara* (for determining *tithi*).

(i) Find *bhogyakhaṇḍa* (or *eṣyakhaṇḍa*) of *vṛtta*. Divide it by 6 and the result is taken in degrees (*amśas*) etc.

(ii) Divide the *amśas* obtained in step (i) by 3 and add $30°$ to it.

(iii) Subtract the result of (i) from that of (ii). This gives *hara*.

i.e., $$Hara = \left(30° + \frac{amsas}{3}\right) - \frac{Bhogyakhaṇḍa}{6}$$

Example : *Vṛtta* = $1^R \, 25° \, 3' \, 52''$, *Bhogyakhaṇḍa* of *vṛtta* = 9 (obtained in the previous *śloka*)

(i) $\dfrac{Bhogyakhaṇḍa}{6} = \dfrac{9}{6} = 1° \; 30'$

(ii) $\dfrac{aṃśa \text{ obtained in(i)}}{3} + 30° = \dfrac{1°}{3} + 30° = 20' + 30° = 30° \; 20'$

(iii) $\therefore$ *Hara* = step (ii) – step (i)

$= 30° \; 20' - 1° \; 30' = 28° \; 50'$

Now, *Cara* must be obtained (as explained in *Ravicandra spaṣṭādhikāra, Ślokas* 5 and 6) from the true longitude of the Sun.

Example : We have, *Nirayana* Ravi : $6^R \; 29° \; 58' \; 19''$

Ayanāṃśa : $18° \; 10'$ and hence

Sāyana Ravi : $7^R \; 18° \; 08' \; 19''$ and *Cara* = + 84

***Śloka* 12** : The method of obtaining true (*spaṣṭa*) *tithi* is explained :

(i) Consider *phalasamskṛti* (i.e., *Raviphalam* + *Candraphalam*, obtained in *Śloka* 10). Multiply this by 10 and divide by *hara*. The result will be in *ghaṭīs*.

(ii) Find *cara*. If *cara* is positive, then consider it as negative. If *cara* is negative consider it as positive (i.e., take the opposite sign).

(iii) Consider the *deśāntara* distance in *yojanas*. Subtract $\frac{1}{4}$ of *deśāntara* distance from itself. The result is called *deśāntaraphalam*.

Cara is subtracted from the *deśāntaraphalam*, given by *deśāntara* in *yojanas* reduced by $\frac{1}{64}$ of it (taken positive or negative according as the place is to the east or west of the Ujjaiyinī meridian). This has to be added

to or subtracted from (according as it is $+^{ve}$ or $-^{ve}$) the result obtained in item (i).

Example : We have, from the example under *Ślokas* 10 and 11

Phalasamskṛti = $+38° 3' 57''$

and *hara* = 28|50

(i) $$\frac{Phalasamskṛti \times 10}{hara} = \frac{(38|3|57) \times 10}{28|50} = +13|12$$

(ii) We have *Cara* = + 84

(iii) *Deśāntara yojanam* = 64 *yojanas.*

Now, $$64 - \frac{64}{4} = 48$$

(iv) Taking the *opposite sign* for the *cara* (i.e., – 84), we have

– *Cara* + 48 = – 84 + 48 = – 36

Phalatraya samskṛti = 13′ 12″ – 0′ 36″ = 12′ 36″ (in *kalās*)

(v) *Tithi* = 5^{d} 20^{gh} 8^{vig} (mean *tithi vārādika* obtained under Śloka 6).

The *phalatraya sanskṛti* 12 | 36, considered as ghaṭīs, being additive, with the **mean** *vārādi* of *tithi* gives true *vārādi* of *tithi* as $5^{d}32^{gh}44^{vig}$.

(vi) We have obtained earlier (in example under Śloka 6):

Nirayaṇa Mean Ravi : 6^{R} 29° 58′ 19″

Phala-traya-saṃskāra : + 12′ 36″

	Corrected Nirayaṇa Ravi:	$7^R\ 0°\ 10'\ 55''$
(vii)	*Vyagu* (obtained earlier):	$5^R\ 25°\ 08'\ 15''$
	(According *Viśvanātha*) :	
	Phala-traya-samskāra :	$+\ 12'\ 36''$
	Corrected *vyagu:*	$5^R\ 25°\ 20'\ 51''$

***Śloka* 13** : The method of obtaining true Sun and true *vyagu* is explained as follows.

(i) Multiply *Raviphalam* by 4. The result will be in *kalās.*

(ii) Divide the above result by 24.

(iii) Add the results of step (i) and step (ii).

(iv) The result of step (iii) is added to or subtracted from Ravi accordingly to get *spaṣṭa* Ravi. Similarly the same result of step (iii) is added to or subtracted from *vyagu* to get *spaṣṭa vyagu.*

(v) Add $\left(2 - \frac{1}{3}\right)$ to *hara.* Divide this by 3. The result gives the diameter of the Moon in *aṅgulas.* The moon's diameter

i.e., $$Candrabimbam = \frac{hara + \left(2 - \frac{1}{3}\right)}{3} \text{ } aṅgulas.$$

Example : We have *Raviphalam* = $23'\ 3''\ 20'''$

(i) *Raviphalam* $\times\ 4\ =\ 92'\ 13''\ 20'''$

(ii) $\dfrac{Raviphalam \times 4}{24} = 3' \, 50'' \, 33''$

(iii) $92' \, 13'' \, 20''' + 3' \, 50'' \, 33''' = 96' \, 3'' \, 53''' = 1°36'3''53'''$

(iv) Ravi (obtained earlier from *Śloka* 12) : $7^R \, 0° \, 10' \, 55''$

Since (iii) is subtractive, we get

Spaṣṭa Ravi $= 7^R \, 0° \, 10' \, 55'' - (1° \, 36' \, 3'' \, 53''')$

i.e. **True Ravi** $= 6^R 28°34'52''$ (neglecting $53'''$)

(iv) (Earlier obtained) *Vyagu* = $5^R \, 25° \, 20' \, 51''$

Subtracting item (iii) : $-1° \, 36' \, 3''$ (neglecting $53'''$)

True *Vyagu* : $5^R 23°44'48''$

(v) Now, we have

$$Candrabimbam = \frac{hara \times \left(2 - \frac{1}{3}\right)}{3} \text{ } a\dot{n}gulas$$

$$= \frac{28|50 \times \left(2 - \frac{1}{3}\right)}{3} \text{ } a\dot{n}g. = \frac{30|30}{3} \text{ } a\dot{n}g. = 10|10 \text{ } a\dot{n}gulas$$

i.e., Diameter of the Moon = $10|10$ *aṅgulas*

Śloka 14 : This *śloka* explains the method of finding the diameters of the Sun and earth's shadow.

For the *Ravibimbam* (Sun's diameter) :

(i) Consider $\left(11-\frac{1}{6}\right) = 10|50$ *aṅgulas*

(ii) Divide *bhogya* (*agrima*) *khaṇḍa* by 40.

(iii) According as the Ravi *(manda) kendra* is from $90°$ to $270°$ (II or III quadrant) or from $270°$ to $90°$ (IV or I quadrant) item (ii) must be *added to* or *subtracted from* item (i). This gives

$$Ravibimbam = (10|50) \pm \frac{Agrimakhaṇḍa}{40}$$

(iv) The diameter of the earth's shadow cone

$$Bhūbhābimbam = (Hara - 5) + \frac{Hara - 5}{15} \pm \frac{Agrimakhaṇḍa}{50}$$

where $+^{ve}$ sign or $-^{ve}$ sign is taken according as Ravi *(manda) kendra* is between $270°$ and $90°$ (i.e., IV or I quadrant) or between $90°$ and $270°$ (i.e., II or III quadrant).

Example : *Agrimakhaṇḍa* (i.e., the last of the elapsed *khaṇḍas*) of the Sun's *manda kendra* is 12 (obtained in *Śloka* 10). Therefore,

(1) ***Ravibimbam*** $= (10|50) - \frac{12}{40} = 10|32$ *aṅgulas*

Note that the Ravi *(manda) kendra* = $228° \, 1' \, 41''$ (lying in III quadrant).

(2) *Bhūbhābimbam* : Here, *hara* = $28|50$.

$\therefore$ Earth's shadow diameter

$$= (28|50-5) + \frac{28|50-5}{15} - \frac{12}{50} = (23|50) + \frac{23|50}{15} - \frac{12}{50}$$

$$= 23|50 + 1|35 - 0|14 = 25|11 \text{ } \textit{aṅgulas}.$$

***Śloka* 15** : Here the possibility (or otherwise) of an eclipse is explained.

As explained earlier, the *tithi* etc. (i.e., *tithi, śara, bimba* etc.) are used for determining an eclipse. After the occurrence of an eclipse, a fortnight earlier or later than six months hence (i.e., $5\frac{1}{2}$ or $6\frac{1}{2}$ months) or a fortnight hence, the possibility of an eclipse is to be found out. If the *bhujāṃśa* is less than 15° an eclipse is possible. Further, if the (southern) *bhujāṃśa* of the *vyagu* is less than 8°, then the possibility of a solar eclipse has to be considered. If the duration of the day is greater than that of the *tithi* (new moon), then a solar eclipse can be considered. On the otherhand, if the *tithi* (full-moon) ends after the sunset, a lunar eclipse can be considered.

***Śloka* 16** : This *śloka* explains the method of finding *grāsa* (or *channam*) in the case of a lunar eclipse as follows.

(i) Subtract $3|20$ from *hara* and multiply the difference by 4.

(ii) Divide the above result by 9.

(iii) Subtract the *bhujāṃśa* of *vyagu* from the result of step (ii) and multiply the difference by 11.

(iv) Divide the result of step (iii) by 7. This gives *channam* or *grāsa* in *aṅgulas* in the case of a lunar eclipse.

i.e., *Grāsa* (or *Channam*) = $\left\{\frac{(hara - 3|20)\,4}{9} - bhuja \text{ of } vyagu\right\} \times \frac{11}{7}$

Note : If the *bhuja* of *vyagu* is greater than the result of step (ii) then there is *no eclipse.*

Example : We have, *hara* = $28|50$

(i) $(28|50 - 3|20) \times 4 = 102|0$

(ii) $\frac{102|0}{9} = 11|20$

(iii) *Vyagu bhujāṃśa* = $6|15|12$

Now, $11|20|0 - 6|15|12 = 5|4|48$

(iv) *grāsa* = $\frac{5|4|48 \times 11}{7} = \frac{55|52|48}{7} = 7|58$ *aṅgulas*

***Śloka* 17** : This *śloka* gives the method of finding *grāsa* (or *Channam*) in the case of a solar eclipse as follows.

(i) Find *darśānta* and *natam* at *darśānta.*

(ii) Divide *natam* by 4. The result will be in *rāśis.*

(iii) In the case of *pūrva* (i.e., eastern) *nata* subtract $\frac{1}{4} \times nata$ from the Sun, and in the case of *paścima* (i.e., western) *nata* add $\frac{1}{4} \times nata$ to the

Sun. This gives *the nata* corrected Sun.

(iv) Find the *krānti* (declination) of the *nata* corrected Sun.

(v) Now, *natāṃśa* = *krānti* ±*akṣāṃśa* $\equiv(\delta-\phi)$

(vi) Divide *natāṃśa* by 6.

(vii) Add the result of step (vi) to *vyagu bhujāmśa* if *natāmśa* and *vyagu* are in the same direction. Otherwise, subtract the result of step (vi) from *vyagu bhujāṃśa.*

(viii) Subtract the result of step (vii) from 7 and divide it by 2. Then

(ix) $Gr\bar{a}sa = (7 - step\ (vii)) + \left(\dfrac{7 - step\ (vii)}{2}\right)$

in *aṅgulas* in the case of a solar eclipse.

Note : If it is not possible to subtract the result of step (vii) from 7. (i.e., step (vii) > 7) then *there is no eclipse*

Example : *Smavat* 1669, *Śaka* 1534, *Vaiśākha kṛṣṇa* 30 (*amāvāsyā*), Wednesday, *Cakra* 8, *Māsagaṇa* = 51. End of the *amāvāsyā* i.e., *amānta* = $26|40$ *gh.*

(i.e. May 30, 1612 (G) A.D., Wednesday).

We have

dinārdham = $16|48$ gh.

(i) *nata* = $9|52$ in the west (obtained as explained earlier)

(ii) $\dfrac{nata}{4} = \dfrac{9|52}{4} = 2^R|14^\circ$

(iii) *nata* corrected Ravi = $4^R\ 5^\circ\ 26'\ 34''$

(iv) *krānti* of the *nata* corrected Ravi = $13^\circ\ 52'\ 22''$ (north) $\equiv \delta$

(v) *akṣāṃśa* = $25^\circ\ 26'\ 42'' \equiv \phi$

$\therefore$ *natāṃśa* $(\delta - \phi) = 13^\circ\ 52'\ 22'' - 25^\circ\ 26'\ 42''$

$= -11^\circ\ 34'\ 20''$ *i.e.*, $11^\circ\ 34'\ 20''$ (south)

(vi) $\dfrac{\textit{natāṃśa}}{6} = \dfrac{11^\circ\ 34'\ 20''}{6} = 1^\circ\ 55'\ 43''$ (south)

(vii) *vyagu bhujāṃśa* = $7^\circ\ 59'\ 36''$ (north)

Now $7^\circ\ 59'\ 36'' - 1^\circ\ 55'\ 43'' = 6^\circ\ 3'\ 53''$

(viii) $7^\circ - 6^\circ\ 3'\ 53'' = 0^\circ\ 56'\ 7''$

(ix) $\dfrac{0^\circ\ 56'\ 7''}{2} = 0^\circ\ 28'\ 3''$

$\therefore$ *Grāsa* = $0|56|7 + 0|28|3 = 1|24$ *aṅgulas*

***Śloka* 18** : This *śloka* explains the determination of the *parveśa* (Lord of the *parva*).

(i) Find the mean *vyagu* using the *māsagaṇa*. Divide the number in the *rāśi* position by 12. This result is called *vyagu madhya paryāya gaṇa*

(ii) Multiply the above result by 2.

(iii) If *vyagu* is greater than 180° add 1 to it.

(iv) Add *cakra* to the above result and then divide by 7. The remainder gives the *parveśa* as follows :

Remainder	***Parveśa***
1	*Brahmā*
2	*Candra*
3	*Indra*
4	*Kubera*
5	*Varuṇa*
6	*Agni*
7 or 0	*Yama*

Note : The remainder indicates *gataparveśa;* to get the present (*vartamāna*) *parveśa*, add 1 to it.

Śloka 19 : Now, the determination of the Moon's position from that of the Sun is explained.

(i) Multiply the *tithi* number by 12. The result will be in degrees.

(ii) Add the above result to the *spaṣṭa* Ravi.

(iii) Multiply *hara* by 24 and add 62 to the product. This gives *candragati* (i.e., daily motion of the Moon) in *kalās*. i.e., *Candragati* = (*hara* $\times$ 24) + 62

(iv) *Sūrya gati* (daily motion of the Sun) = $59'\,08''$

(v) Find the *tithikāla* using the Sun and the Moon obtained above.

(vi) Also find the *gata* (elapsed) and the *gamya* (balance) *ghaṭīs* of the *nakṣatra* and *yoga*.

Example : *Thithi* = 15, Ravi : $6^R\ 28°\ 34'\ 52''$ and *hara* = $28|50$

(i) *Spaṣṭa* Candra = $(15 \times 12)° + 6^R\ 28°\ 34'\ 52'' = 0^R\ 28°\ 34'\ 52''$

(removing 12 *rāśis)*

(ii) *Candragati* = $28|50 \times 24 + 62 = 754'$.

CHAPTER 8

GRAHAṆADVAYA SĀDHANĀDHIKĀRAḤ

(Eclipses from *Pañcāṅga* - Shortcut Method)

***Śloka* 1** : Now, the computations of the two eclipses (solar and lunar) by a shorter method based on the data from the *pañcāṅga* (almanac) viz., *parvānta* (end of the lunar fortnight), postions of the Sun, the Moon and Rāhu, *gata* (elapsed) and *eṣya* (balance) *ghaṭīs* of *tithi* and *nakṣatra*, duration of the day (from sunrise to sunset) are explained.

Example : We have the following data from *pañcāṅga* :

Samvat year = 1669, *Śaka* year = 1534

Vaiśākha Śukla Pūrṇimā, Monday [i.e. May 14-15, 1612 (G)]

The elapsed portion of *Pūrṇimā*

$$\textit{gataghaṭī} = 2|23 \ gh.$$

The balance portion of *Pūrṇimā*

$$\textit{eṣyaghaṭī} = 54|20 \ gh.$$

Sum of the *gata* and the *eṣya ghaṭīs,*

$$\textit{Tithiyoga ghaṭī} = 2|23 + 54|20 = 56|43 \ gh.$$

gataghaṭīs of the *Anurādhā nakṣatra* = $20|4$ *gh.*

eṣyaghaṭīs of *Anurādhā* = $38|35\, gh.$

Sum of the *gata* and *eṣya ghaṭīs* of *Anurādhā nakṣatra*

= $20|4 + 38|35 = 58|39\, gh.$

Dinamānam = $33|6\ gh.$

Ravi at *parvānta* = $1^R\ 6^\circ\ 34'\ 37''$

Rāhu at *parvānta* = $1^R\ 14^\circ\ 18'\ 11''$

Virāhvarka = (Sun – Rāhu) = $11^R\ 22^\circ\ 16'\ 26''$

***Śloka* 2** : This *śloka* explains the method of finding *channam* (*grāsa*) as follows :

(i) Subtract 7 from *tithiyoga ghaṭī* (i.e., the sum of the *gata* and *the eṣya ghaṭīs* of the *tithi*)

(ii) Divide 627 by the result of step (i). The result will be in *aṃśas*.

(iii) Subtract *bhujāṃśa* of *vyagu* from item (ii).

(iv) Add $\frac{1}{16}$ of item (iii) + and $\frac{1}{2}$ of item (iii) to item (iii) i.e., take the sum : item (iii) + $\frac{1}{16}$ item (iii) + $\frac{1}{2}$ item (iii).

This sum gives *grāsa* or *channam* in *aṅgulas*.

i.e., Let $x = \left[\dfrac{627}{tithiyoga - 7} - bhuj\bar{a}\dot{m}\acute{s}a\ of\ vyagu\right]$,

$$\text{Then, } \textit{grāsa (channam)} = x + \frac{x}{16} + \frac{x}{2} \ \textit{aṅgulas}$$

Example : *Tithiyoga* = $56|43$ *gh. and Vyagubhuja* = $7^\circ\ 43'\ 34''$

$$\text{Then } x = \left[\frac{627}{56|43 - 7|0} - 7^\circ\ 43'\ 34''\right] = 4|53|7$$

$$\textit{grāsa (channam)} = x + \frac{x}{16} + \frac{x}{2} = 7|37|59 \ \textit{aṅgulas}$$

***Śloka* 3** : This *śloka* gives the formula for finding diameters of the Moon and earth's shadow in the case of lunar eclipse as follows :

(1) **The diameter of the Moon,**

$$\textit{Candrabimbam} = \frac{695}{\textit{tithiyoga} + 6} \ \textit{aṅgulas}$$

(2) The diameter of the earth's shadow

$$\textit{Bhūbhābimbam} = \frac{1322}{\textit{tithiyoga} - 10} \ \textit{aṅgulas}$$

Example : *Tithiyoga ghaṭī* = $56|43$ *gh.*

$$(1)\ \textit{Candrabimbam} = \frac{695}{56|43 + 6} = 11|4 \ \textit{aṅgulas}$$

$$(2)\ \textit{Bhubhābimbam} = \frac{1322}{56|43 - 10} = 28|17 \ \textit{aṅgulas.}$$

Śloka 4 : This *śloka* gives the method of finding *grāsa* using *nakṣatra ghaṭī.*

It is as follows :

(i) Subtract 10 from *nakṣatrayoga ghaṭī* (sum of *gata* and *eṣya gaṭīs* of *nakṣatra*)

(ii) Divide 610 by item (i).

(iii) Subtract *bhujāṃśa* of *vyagu* from item (ii).

(iv) Multiply item (iii) by 11.

(v) Divide item (iv) by 7. This gives *grāsa* in *aṅgulas.*

$$\text{i.e., } Grāsa = \left[\frac{610}{Nakṣatrayoga\ ghaṭī - 10} - Bhujāṃśa\,of\,vyagu\right] \times \frac{11}{7}\ aṅg$$

Example : *Nakṣatrayoga ghaṭī* = $58|36$ *gh.*

Vyagu bhujāṃśa = $7°\ 43'\ 34''$

$$\therefore grāsa = \left[\frac{610}{58|36-10} - 7°\ 43'\ 34''\right] \times \frac{11}{7} = 7|34\ aṅgulas$$

Remark : We had obtained earlier (from *śloka* 2) *grāsa* = $7|37|59$ *aṅgulas* using *tithi yoga ghaṭīs.*

Viśvanātha in his commentary gives a correction (*samskāra*) to the ***bhūbhābimbam*** (diameter of the shadow cone) as follows :

Consider the following values in *pratyaṅgulas* for six *rāśis* : 11, 16, 20,

16, 11, 0. If Ravi is within 6 *rāśis* from *Meṣa* then *add* the corresponding value for that *rāśi* to the *bhūbhābimbam* (obtained earlier from *Śloka* 3). If Ravi is in a *rāśi* among the six *rāśis* from *Tulā* then *subtract* the corresponding values.

Example : The *bhūbhābimbam* obtained earlier : $28|17$ *aṅgulas*.

$$\text{Ravi} = 1^R\, 6^\circ\, 34'\, 37''$$

i.e., in the second *rāśi* from *Meṣa*. The corresponding value in *pratyaṅgulas* is 16. Therefore, corrected *bhūbhābimbam* = $28|17 + 0|16 = 28|33$ *aṅgulas*.

***Śloka* 5** : This *śloka* gives the method of finding the *candrabimbam* (diameter of the Moon) and the *bhūbhābimbam* (diameter of earth's shadow) using *nakṣatrayoga ghaṭī*. It is as follows :

$$(1)\ \textit{Candrabimbam} = \frac{649}{\textit{nakṣatrayoga ghaṭī}}\ \textit{aṅgulas}$$

$$(2)\ \textit{Bhūbhābimbam} = \frac{1255}{\textit{nakṣatrayoga ghaṭī} - 14}\ \textit{aṅgulas}$$

Example : *Nakṣatrayoga ghaṭī* = $58|36$

$$(1)\ \textit{Candrabimbam} = \frac{649}{58|36} = 11|4\ \textit{aṅgulas}$$

$$(2)\ \textit{Bhūbhābimbam} = \frac{1255}{58|36 - 14} = 28|8\ \textit{aṅgulas}$$

Viśvanātha's suggested correction (under *Śloka* 4) yields :

$$Bh\bar{u}bh\bar{a}bimbam = 28|8 + 0|16 = 28|24 \text{ a\.{n}gulas}$$

Remark : Viśvanātha gives another method for obtaining *bhūbhābimbam* (and its correction) :

$$Bh\bar{u}bh\bar{a}bimbam = \frac{1200}{Nak\d{s}atrayoga\ gha\d{t}\bar{\imath} - 16}$$

$$= \frac{1200}{58|36 - 16} = 28|10 \text{ a\.{n}gulas}$$

$\therefore$ Corrected *bhūbhābimbam* = $28|10 + 0|16 = 28|26$ *aṅgulas*

***Śloka* 6** : This *śloka* explains the method of finding *grāsa* (*channam*) of solar eclipse using *tithi ghaṭī*. It is as follows.

(i) Divide 170 by *tithighaṭī*.

(ii) Add 4 to item (i).

(iii) Subtract *vyagusphuṭa bhujāṃśa* from item (ii) [see note below].

(iv) Multiply item (iii) by 11, and divide the product by 7. This gives *grāsa* of Ravi in *aṅgulas*.

i.e., $$gr\bar{a}sa = \left[\left[\left(\frac{170}{tithi\ gha\d{t}\bar{\imath}}\right)+4\right] - vyagu\ sphu\d{t}a\ bhuj\bar{a}\d{m}\d{s}a\right]\times\frac{11}{7}$$

aṅgulas

Example : On a solar eclipse day, *Tithighaṭī* = $64|49$

Vyagusphuṭa bhujāṃśa = $1^\circ\ 56'\ 45''$

$$\textit{Grāsa} \text{ of Ravi} = \left[\left(\frac{170}{64|49} + 4\right) - 1^\circ\ 56'\ 45''\right] \times \frac{11}{7} = 7|20|58 \ \textit{aṅgulas}$$

Another Method for *grāsa* of Ravi :

Another method of finding *grāsa* of Ravi using *nakṣatraghaṭī* is as given below :

(i) Divide 233 by *nakṣatraghaṭī*. The result will be in *amśas.*

(ii) Add 3 to item (i).

(iii) Subtract *vyagu sphuṭa bhujāṃśa* from item (ii).

(iv) Multiply item (iii) by 11, and divide by 7. This gives *grāsa* of Ravi in *aṅgulas.*

i.e., *Grāsa* of Ravi

$$= \left[\left(\frac{233}{\textit{nakṣatraghaṭī}} + 3\right) - \textit{vyagu sphuṭa bhuja}\right] \times \frac{11}{7}$$

Example : On a solar eclipse day, *Nakṣatraghaṭī* = $65|56$

$$\therefore\ \textit{Grāsa} = \left[\left(\frac{233}{65|56} + 3\right) - 1^\circ\ 56'\ 45''\right] \times \frac{11}{7} = 7|12|35 \ \textit{aṅgulas}$$

We notice a small difference of only about 8 *pratyaṅgulas.*

Note : To find *vyagusphuṭa bhujāṃśa* used above :

For the given date : *Śaka* 1432, *Mārgaśira kṛṣṇa amāvāsyā* Wednesday, we have the following :

gata tithi ghaṭī = $51|50$, *eṣya ghaṭī* = $12|59$

tithiyoga ghaṭī = $64|49$, *nakṣatrayoga ghaṭī* = $65|56$

[*gataghaṭī* = $13|54$ and *eṣyaghaṭī* = $52|2$]

dinamānam = $26|4$ *gh.*

Ravi at the end of the *tithi* = $8^R\ 5°\ 26'\ 20''$

Rāhu = $2^R\ 11°\ 41'\ 18''$, *vyagu* = $5^R\ 23°\ 45'\ 2''$, and *natam* = $1°30'$

Now, we have

nata corrected Ravi = $\text{Ravi} - \frac{1}{4} \times \textit{natam} = 8^R\ 5°\ 3'\ 50''$

Krānti of the *nata* corrected Ravi, $\delta = -23°\ 43'\ 40''$, *Akṣāṃśa* $= 25°\ 26'\ 42'\ N$

Natāṃśa = $\delta - \phi = 49°\ 10'\ 22''$ (south)

Vyagu bhujāṃśa = $6°\ 14'\ 58''$

Sphuṭa vyagu bhujāṃśa = $\frac{1}{6} \times \textit{natāṃśa} - \textit{vyagubhuja}$

$$= \frac{1}{6} \times 49°\ 10'\ 22'' - 6°\ 14'\ 58'' = 1°\ 56'\ 45''$$

***Śloka* 7** : This *śloka* gives the method of finding the *sūryabimbam* (diameter of the Sun) as follows :

(i) Add $12°$ to Ravi. Consider the *bhuja* of it.

(ii) Divide item (i) by 3. The result will be in *aṅgulas*, *pratyaṅgulas* etc. Consider the number in the *aṅgula* position.

(iii) Consider $11-\frac{1}{6}=10|50$ *aṅgulas (i.e. mean sūryabimbam)*

(iv) If Ravi is within 6 *rāśis* from *Meṣa* (i.e., $0° < \text{Ravi} < 180°$) subtract item (ii) from item (iii).

If Ravi is within 6 *rāśis* from *Tulā* (i.e., $180° < \text{Ravi} < 360°$) add item (ii) to item (iii). This gives *sūryabimbam* in *aṅgulas*.

Example : Ravi = $8^R\ 5°\ 26'\ 20''$

(1) Adding $12°$ to Ravi, we get $8^R\ 5°\ 26'\ 20'' + 12° = 8^R\ 17°\ 26'\ 20''$ and its

bhujāṃśa = $77°\ 26'\ 20''$

(2) $\frac{bhujāṃśa}{3} = \frac{77°\ 26'\ 20''}{3} = 25|48|46$ *aṅgulas*

Now, the number in the *aṅgula* position = 25

(3) $11-\frac{1}{6} = 10|50$ *aṅgulas*

(4) Since Ravi is within 6 *rāśis* from Tulā, we have

Ravibimbam = $10|50 + 0|25 = 11|15$ *aṅgulas.*

CHAPTER 9

UDAYĀSTĀDHIKĀRAḤ

(Rising and Setting of Planets)

In this chapter the rising and setting of the Sun, the Moon and the planets are discussed. On the first day (*pratipat*) of the bright fortnight whether the Moon is visible or not is determined.

Śloka 1: **To find *prathamaphalam* :**

(i) Find the Sun, the Moon, Rāhu and *virāhvarka* (*vyagu*) at the end of the *pratipat*. Add 12° to both, the true Sun and the *vyagu*.

(2) Find the *cara* of *virāhvarka* (i.e., of *vyagu*)

(3) Divide the *cara* by 56. This result is called *prathamaphalam*.

If the *vyagu* is in the *uttaragola*, the above result is positive and if the *vyagu* is in the *dakṣiṇagola* the result is negative.

i.e., $$prathamaphalam = \frac{cara\ of\ vyagu}{56}$$

Note : *Vyagu* is said to be in the *uttaragola* (northern hemisphere) if $0^\circ < vyagu < 180^\circ$ and in the *dakṣiṇagola* (southern hemisphere) if $180^\circ < vyagu < 360^\circ$.

Example : The given date is as follows :

Śaka 1532, *Māgha śukla pratipat,* Saturday i.e., Jan. 15, 1611 (G).

For the above date, *Cakra* = 8, *Ahargaṇa* = 1036

Śravaṇa nakṣatra ghaṭī = 28|25, *Siddhayoga ghaṭī* = 40|8

Mean Sun = $9^R\ 6^\circ\ 12'\ 37''$, Mean Moon = $9^R\ 19^\circ\ 38'\ 33''$

Candrocca = $8^R\ 20^\circ\ 54'\ 28''$, Rāhu = $2^R\ 10^\circ\ 3'\ 25''$

As given in the *pañcāṅga, Tithighaṭī* = 7 *gh.*

(i.e., the end of *pratipat* after sunrise)

At this instant we have

Mean Sun = $9^R\ 6^\circ\ 19'\ 31''$, Mean Moon = $9^R\ 21^\circ\ 10'\ 47''$

Rāhu = $2^R\ 10^\circ\ 3'\ 3''$, *Cara* = $106'$

True Sun = $9^R\ 7^\circ\ 2'\ 44''$, True Moon = $9^R\ 18^\circ\ 52'\ 12''$

True daily motion of the Sun = $61'\ 10''$

True motion of the Moon = $735'\ 01''$

Ayanāṃśa = $18^\circ\ 8'$, *Tithi* (*pratipat*) = 1

We shall find the instant of the ending of the *pratipat*. After the instant of new moon, for the end of *pratipat*, the moon has to cover 12° away from the Sun. Now, True Moon – True Sun = $11^\circ\ 49'\ 28''$. To complete 12° the Moon has to cover, relative to the Sun, $12^\circ - 11^\circ\ 49'\ 28'' = 10'\ 32''$. The difference in the daily motions of the Moon and the Sun = $735'\ 01'' - 61'\ 10'' = 673'\ 51''$. Therefore, the balance of time taken till the end of *pratipat* is

$$\frac{10'\,32''}{673'\,51''} \times 60^{gh} \approx 56\, vig.$$

Adding this to the *pañcāṅga* given *tithi ghaṭī*, we get

$$\text{End of } pratipat = 7gh + 0|56gh = 7|56\,gh$$

To find *prathamaphalam* (the first result) :

At the end of *pratipat,* we have

$$\text{True Ravi} = 9^R\, 7^\circ\, 3'\, 41''$$

$$\text{True Rāhu} = 2^R\, 10^\circ\, 3'\, 1'',\ vyagu\ (virāhvarka) = 6^R\, 27^\circ\, 0'\, 40''$$

Adding 12° to both true Ravi and *vyagu*, we get respectively $9^R\, 19^\circ\, 3'\, 41''$ and $7^R\, 9^\circ\, 0'\, 40''$. For this, *cara* = 70.

Note : In the text it is printed as 6^R in place of 9^R in the case of the Sun.

Now, we have

$$prathamaphalam = \frac{cara}{56} = \frac{70}{56} = 1|15|0$$

Since *vyagu* is in the *dakṣiṇagola*, the *prathamaphalam* is negative.

$$\text{i.e.,}\quad Prathamaphalam = -1|15|0$$

***Ślokas* 2 and 3** : These two *ślokas* explain the method of finding *dvitīyaphalam*, *tṛtīyaphalam* and *caturthaphalam* as follows.

(1) **To find *dvitīyaphalam* (the second result)** :

(i) Consider *satribha sāyana* Ravi.

(i.e., *Nirayaṇa* Ravi + 3^R + *Ayanāṃśa*)

Find the *cara* of the *satribha sāyana* Ravi.

(ii) Multiply the *cara* and the magnitude of *prathamaphalam*.

(iii) Multiply the *palabhā* by 2. Square the product.

(iv) Divide the result of step (ii) by that of step (iii). This result is called *dvitīyaphalam*.

i.e., $$Dvit\bar{\imath}yaphalam = \frac{|Prathamaphalam| \times Cara}{(2 \times palabha)^2}$$

It is positive if Ravi and the *Vyagu* are in different *gola*s, and negative if they are in the same *gola*.

(2) To find *tṛtīyaphalam* (the third result) :

(i) Find the *udayamāna* of *saṣaḍbha sāyana* Ravi [i.e., *sāyana* Ravi + 6 *rāśis*].

(ii) Take the difference of 300 and *udayamāna* of *saṣaḍbha sāyana* Ravi.

(iii) Divide the above difference by 25. The result is positive if the *udayamāna* of *saṣaḍbha sāyana* Ravi is greater than 300 *vig.* and it is negative if the *udayamāna* of *saṣaḍbha sāyana* Ravi is less than 300 *vig.*

i.e., $$T\d{r}t\bar{\imath}yaphalam = \frac{Udayam\bar{a}na - 300}{25}$$

(3) To find *caturthaphalam* (the fourth result) :

(i) Consider the difference between the *dinamānam* and the end of the *tithi.*

(ii) Divide the above difference by 5. This gives *caturthaphalam.*

i.e., $$Caturthaphalam = \frac{dinam\bar{a}nam - end\,of\,the\,tithi}{5}$$

To find *Candrodaya* at *pratipat* :

Find *prathama, dvitīya, tṛtīya* and *caturthaphalas.* Add all the four. If the resulting sum is positive, then *Candra* (Moon) is visible. If the sum is negative, *Candra* is not visible.

Example :

Satribha sāyana Ravi = $1^R\ 7^\circ\ 11'\ 41''$, *Cara* of the above = $68'$

Prathamaphalam = $-1|15|0$, *Palabhā* = $5|45$ *aṅgulas*

$$Dvit\bar{i}yaphalam = \frac{|prathamaphalam| \times cara}{(2 \times palabha)^2}$$

$$= \frac{(1|15|0) \times 68'}{(2 \times 5|45)^2} = +\,0|38|33$$

Since *vyagu* and Ravi are in different *golas, dvitīyaphalam* is positive.

Saṣaḍbha sāyana Ravi = $4^R\ 7^\circ\ 11'\ 41''$

Udayamāna of the *rāśi* of the above = 345 *vig.*

[i.e., *udyamāna* of *Siṃha rāśi* for *Kāśi*]

$$Tṛtīyaphalam = \frac{Udayamāna - 300}{25}$$

$$= \frac{345-300}{25} = \frac{45}{25} = +1|48|0$$

Since *udayamāna* > 300, the *tṛtīyaphala* is positive.

$$Dinamānam = 26|28 \; ghaṭīs$$

The end of the *pratipat* = $7|56$ *ghaṭīs*

$$Caturthaphalam = \frac{dinamāna - \text{end of the } tithi}{5}$$

$$= \frac{26|28 - 7|56}{5} = +3|42|14$$

Since *dinamāna* > end of the *tithi*, the *caturthaphala* is positive.

To find *Candrodaya* on *śukla pratipat* :

Sum of the four *phalas* = $-1|15|0 + 0|38|33 + 1|48|0 + 3|42|14 = +4|53|47$

Since the sum of all the four *phalas* is positive, the Moon is *visible*.

(i.e., *Candrodaya* will have taken place before the end of the *pratipat*).

***Śloka* 4** : This *śloka* explains the method of finding the rising and setting of the planet Guru (Jupiter) by using *māsagaṇa*. It is as follows :

(i) Add *cakra* to *māsagaṇa*.

(ii) Divide *cakra* by 13.

(iii) Subtract item (ii) from item (i).

(iv) Multiply item (iii) by 2. Add 10 *māsas* and 11 days to the product.

(v) Divide item (iv) by 27. Consider the remainder.

(vi) Subtract the above remainder from 27.

(vii) Divide the above difference by 2. The result will be in *rāśis*, *amśas* etc.

(viii) Subtract 15° from item (vii).

(ix) Find the *bhuja* of item (viii).

(x) Divide item (ix) by 12. If the result is within 6 *rāśis* from *Tulā* (i.e., $>180^\circ$) it is negative. If the result is within 6 *rāśis* from *Meṣa* (i.e., $<180^\circ$) the result is positive.

(xi) The result of item (x) is added to or subtracted from item (vii) accordingly.

(xii) Consider the above result. Subtract 15 days from it. This gives the setting of Guru.

(xiii) Add 15 days to the result of (xi). This gives the rising of Guru.

Note : Here *māsas* are counted starting from *Caitra.*

Example : For the given date, *śaka* 1532, *cakra* = 8, *māsagaṇa* = 25.

Completed years from the epoch *(i.e., Śā. śā.* 1442*)* = 90.

(i) *Cakra* + *Māsagaṇa* = 8 + 25 = 33

(ii) $\dfrac{cakra}{13} = \dfrac{8}{13} = 0^m\ 18^d\ 27^{gh}\ 41^{vig}$

(iii) item (i) – item (ii) = $33^m - 0^m\ 18^d\ 27^{gh}\ 41^{vig}$.

$$= 32^m\ 11^d\ 32^{gh}\ 19^{vig}$$

(iv) $[item\ (iii) \times 2] + 10^m\ 11^d$

$= [(32|11|32|19) \times 2] + 10^m\ 11^d\ = 75^m\ 04^d\ 04^{gh}\ 38^{vig}$

(v) $\dfrac{item\ (iv)}{27} = \dfrac{75|04|04|38}{27} = 2 + \dfrac{21|04|04|38}{27}$

i.e., the remainder = $21|04|04|38$

(vi) 27 – remainder = $27 - 21|04|04|38\ = 5|25|55|22$

(vii) Dividing item (vi) by 2, we get

$\dfrac{5|25|55|22}{2} = 2^R\ 27°\ 57'\ 41''$

(viii) item (vii) – 15° $= 2^R\ 27°\ 57'\ 41'' - 15° = 2^R\ 12°\ 57'\ 41''$

(ix) *Bhuja* of $2^R\ 12°\ 57'\ 41'' = 72°\ 57'\ 41''$

(x) $\dfrac{Bhuja}{12} = \dfrac{72|57|41}{12} = 6°\ 4'\ 48''$

(xi) Now, the sum of the results of items (vii) and (x) gives

$2|27|57|41 + 6|4|48\ = 3^m\ 4^d\ 2^{gh}\ 29^{vig}$

(xii) item (xi) – 15 days $= 3^m\ 4^d\ 2^{gh}\ 29^{vig} - 15^d = 2^m\ 19^d\ 2^{gh}\ 29^{vig}$

Here *māsas* are elapsed counted from *Caitra*. Therefore the above result tells that Guru sets after $2^m\ 19^d\ 2^{gh}\ 29^{vig}$ from *Caitra* i.e., on *Jyeṣṭha kṛṣṇa pañcamī.*

(xiii) item (xi) + 15 days = $3^m\ 4^d\ 2^{gh}\ 29^{vig} + 15^d = 3^m\ 19^d\ 2^{gh}\ 29^{vig}$

This implies that Guru rises after $3^m\ 19^d\ 2^{gh}\ 29^{vig}$ from *Caitra*. (i.e., on *Āṣāḍha Kṛṣṇa Pañcamī*).

Note : Guru is also called *Bṛhaspati* and *Mantrī.*

***Śloka* 5, 6, 7** : These three *ślokas* explain the method of finding, *asta* (setting) and *udaya* (rising) of Śukra, as follows :

(a) To find the rising of Śukra in the west and setting in the east :

(1) Multiply *cakra* by 17.

(2) Divide $cakra \times 17$ by 45. Add the quotient which will be in *māsas* etc. to item (1).

(3) Add *māsagaṇa* to item (2).

(4) Add 64^m to the product $5 \times \text{item (3)}$.

(5) Divide item (4) by 99. Consider the remainder.

(6) Subtract item (5) from 99 months.

(7) Divide item (6) by 5. The result will be in *māsas* etc.

(8) Consider the result of item (7). Add 36 days to it. This gives the rising of Śukra in the west. (*paścimodaya* of Śukra).

(9) Subtract 36 days from result of item (7). This gives the setting of *Śukra* in the east (*pūrvāsta*).

Example : *Māsagaṇa* from *Caitra* = 25, *cakra* = 8

(1) $17 \times cakra = 17 \times 8 = 136$ months

(2) $\dfrac{17 \times cakra}{45} + (17 \times cakra) = \dfrac{136}{45} + 136 = 139^m\ 0^d\ 40^{gh}$

(3) *Māsagaṇa* + item (2) = $25^m + 139^m\ 0^d\ 40^{gh} = 164^m\ 0^d\ 40^{gh}$

(4) $64 + [5 \times \text{item (3)}] = 64^m + (5 \times 164^m\ 0^d\ 40^{gh}) = 884^m\ 3^d\ 20^{gh}$

(5) $\dfrac{884^m\ 3^d\ 20^{gh}}{99} = 8 + \dfrac{92^m\ 3^d\ 20^{gh}}{99}$

i.e., remainder = $92^m\ 3^d\ 20^{gh}$

(6) $99^m - \text{item (5)} = 99^m - 92^m\ 3^d\ 20^{gh} = 6^m\ 26^d\ 40^{gh}$

(7) $\dfrac{\text{item (6)}}{5} = \dfrac{6^m\ 26^d\ 40^{gh}}{5} = 1^m\ 11^d\ 20^{gh}$

(8) item (7) + 36 days = $1^m\ 11^d\ 20^{gh} + 36^d = 2^m\ 17^d\ 20^{gh}$

This implies that Śukra rises in the west after the lapse of $2^m\ 17^d\ 20^{gh}$ from *Caitra*. i.e., on *Jyeṣṭha kṛṣṇa tṛtīya.*

(9) item (7) – 36 days = $1^m\ 11^d\ 20^{gh} - 36^d = 0^m\ 5^d\ 20^{gh}$

This implies that Śukra sets in the east after $5^d\ 20^{gh}$ from the beginning of *Caitra*, i.e., on *Caitra Śukla ṣaṣṭī.*

To find the rising of Śukra in the east (*pūrvodaya* of Śukra) and the setting in the west (*paścimāsta* of Śukra)

(1) Consider the *māsas* etc. obtained previously in step (7).

(2) If the above is less than 9 months and 27 days, add $9^m\ 27^d$ to it. If it is greater than $9^m\ 27^d$, subtract $9^m\ 27^d$ from it.

(3) Consider item (2). Add 4 days to it. This gives rising of Śukra in the east.

(4) Subtract 4 days from item (2). This gives setting of Śukra in the west.

Example :

(1) *Māsās* etc. obtained previously in item (7) : $1^m\ 11^d\ 20^{gh}$.

(2) Since it is less than $9^m\ 27^d$, adding $9^m\ 27^d$ we get

$$1^m\ 11^d\ 20^{gh} + 9^m\ 27^d = 11^m\ 08^d\ 20^{gh}$$

(3) item (2) + 4 days = $11^m\ 08^d\ 20^{gh} + 4^d = 11^m\ 12^d\ 20^{gh}$

This implies that Śukra rises in the east after the lapse of $11^m\ 12^d\ 20^{gh}$ from *Caitra* i.e., on *Phālguṇa śuddha trayodaśī*.

(4) item (2) – 4 days = $11^m\ 8^d\ 20^{gh} - 4\ days = 11^m\ 04^d\ 20^{gh}$

This implies that Śukra sets in the west after the lapse of $11^m\ 04^d\ 20^{gh}$ from *Caitra*

i.e., on *Phālguṇa śuddha pañcamī*.

***Śloka* 8** : This *śloka* explains the method of finding *parivartana kāla* (recurrence time) of the rising (*udaya*) and setting (*asta*) of Guru and Śukra. That is, by knowing the *asta* and *udaya* to find the next *udaya* and *asta* of Guru and Śukra.

(1) In the case of Śukra, by adding 19 months and 24 days (*tithis*) to the rising and setting times we get again the next rising and setting of Śukra. Similarly by subtracting the same ($19^m 24^d$), the earlier rising and setting of Śukra are obtained.

(2) In the case of Guru, the period to be added or subtracted is $13^m\ 15^d$.

Remark :

(i) The interval between successive rising and setting or between two successive risings (or settings) of planets given above are only *mean* values. In reality these intervals vary from year to year based on true positions of the Sun and the planets.

For example, the setting (*asta*) of Guru in 1995 was on December 6. The next setting of the same planet was January 8, 1997. The interval (*parivartana*) between these two successive settings of Guru is given by (1997-1-8) – (1995-12-6) = $1^y\ 1^m\ 2^d = 13^m\ 2^d$. The interval given in the text is $13^m\ 15^d$. Similarly, the interval between successive risings is given by 1999-12-30 and 1997-2-2 is $1^y\ 1^m\ 2^d$ i.e., $13^m\ 2^d$.

(ii) The interval given in the text, $13^m\ 15^d$ is actually 13.5 *lunar* months which is equivalent to 13 months, 8 days of the civil calendar.

***Śloka* 9** : This *śloka* gives the method of finding *śara* of Candra as follows.

(1) Consider the *bhuja* of *vyagu*. If *bhuja* is in the first *raśi* i.e., less than

30°, add $\frac{1}{2} \times bhuja$ to *bhuja* of *vyagu*. This gives the *śara* in *aṅgulas.*

(2) If the *bhuja* of *vyagu* is in the second *rāśi* (i.e., $30^\circ \leq bhuja \leq 60^\circ$) add 47 to *bhuja* to get the *śara* in *aṅg.*

(3) If the *bhuja* is in the third *rāśi* (i.e., $60^\circ \leq bhuja \leq 90^\circ$) then add 77 to $\frac{1}{2} \times bhuja$ to get the *śara* in *aṅg.*

Example : Candra = $8^R\, 5^\circ\, 26'\, 20''$, Rāhu = $2^R\, 11^\circ\, 41'\, 18''$

Vyagu = $5^R\, 23^\circ\, 45'\, 02''$, *bhuja* of *vyagu* = $6^\circ\, 14'\, 58''$

Since the *bhuja* of *vyagu* is in the first *rāśi* we have

$$śara = bhuja + \frac{bhuja}{2}$$

$$= 6^\circ\, 14'\, 58'' + \frac{6^\circ\, 14'\, 58''}{2} = 9|22|27 \text{ } aṅgulas$$

Since *vyagu* is in the *uttaragola* (i.e., < 6 *rāśis*), the *śara* is also in the *uttaragola* (i.e., positive or nothern).

***Śloka* 10** : This *śloka* gives another method of finding the *śara* (of the Moon) using *khaṇḍas*. It is as below :

(1) The *śarakhaṇḍas* are

0, 16, 15, 14, 13, 11, 9, 7, 4, 1.

Using these *khaṇḍas* for (Moon – Rāhu) find *śara* by following the same

procedure which is adopted to find the *krānti* using *khaṇḍas*.

Example : *Vyaguvidhu* i.e., (Moon – Rāhu) = $5^R\ 23°\ 45'\ 2''$

(**Note** : The moon is also called *Vidhu*.)

The *bhuja* of the *vyagu* = $6°\ 14'\ 58''$

(1) $\dfrac{6°\ 14'\ 58''}{10} = 0 + \dfrac{6°\ 14'\ 58''}{10}$, remainder = $6°\ 14'\ 58''$

This implies that the *gata* (elapsed) *khaṇḍa* = 0 and

eṣyakhaṇḍa = 16 (from Table 9.1 of *khaṇḍas*)

(2) $\dfrac{\textit{Eṣyakhaṇḍa} \times \text{remainder}}{10} = \dfrac{16 \times 6°\ 14'\ 58''}{10}$

$$= \frac{99°\ 59'\ 28''}{10} = 9|59 \text{ aṅgulas}$$

(3) *gatakhaṇḍa* + item (2) = $0 + 9|59$ *aṅgulas*

i.e., *śara* = $9|59$ *aṅgulas*

Explanation : The *khaṇḍas* for finding the *śara* of the Moon given in *GL* are as follows :

Table 9.1 : *Śara khaṇḍas* of the Moon

Vyagu bhuja	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Difference	16	15	14	13	11	9	7	4	1	
Śara(aṅg)	0	16	31	45	58	69	78	85	89	90

$$\text{For } Vyagu = \begin{cases} 30^\circ: \acute{s}ara = 0+16+15+14=45 \; a\dot{n}gulas \\ 60^\circ: \acute{s}ara = 45+13+11+9=78 \; a\dot{n}gulas \\ 90^\circ: \acute{s}ara = 78+7+4+1=90 \; a\dot{n}gulas \end{cases}$$

Note : The actual formula for *śara* is

$$\acute{S}ara = 90 \sin (Vyagu) \; a\dot{n}gulas$$

(Note that 90 *aṅg.* = 270′).

For example for *Vyagu* = 30°, 60° and 90°, we get from the above formula *śara* = 45, 78 and 90 *aṅgulas.*

According to *GL*, the *śara* of the Moon is obtained as follows.

(i) For $0^\circ < bhuja < 30^\circ$, *śara* = 90 sin (*vyagu*)

$$\text{i.e., } \acute{s}ara \approx 90^\circ \times \left[\frac{72}{120 \times 35} \times vyagu\right] = \frac{54}{35} \times vyagu \approx \frac{3}{2} \; vyagu.$$

[Ref. *GL, Tripraśnādhikāra, Śl.* 22 :

$$120 \sin\theta \approx \frac{72}{35}\theta \;\; \therefore \; \sin\theta \approx \frac{72}{120 \times 35}\theta \text{ where } \theta \text{ is in radians].}$$

(ii) For $30^\circ < bhuja < 60^\circ$

Śara = [Accummulated *śara* upto *bhuja* 30°]

$$+ (78 - 45)\frac{bhuja}{30} \approx 45 + (1.1)\, bhuja$$

GL takes it as 47 + *bhuja* (approxly).

(iii) For $60^\circ < bhuja < 90^\circ$,

$$Śara = [\text{Accumulated } śara \text{ for } bhuja \text{ upto } 60^\circ]$$

$$+(90-78)\times\frac{bhuja}{30} = 78+\frac{12}{30}\ bhuja$$

GL takes this as $77+\frac{1}{2}\times bhuja$.

Remark : The following table provides a comparison between the approximated values of *śara* as per *GL* and the actual values using the formula, $śara = 90^\circ \sin(vyagu)$ *aṅgulas.*

Table 9.2 Comparison of *GL śaras* with actuals

Vyagu	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
GL	0	16	31	45	58	69	78	85	89	90
Actual	0	15.63	30.78	45	57.85	68.94	77.94	84.57	88.63	90

***Śloka* 11** : This *śloka* gives the direction of *udaya* (rising) and *asta* (setting) of the planet.

(1) The planet, whose longitude and daily motion are less than those of the Sun, rises in the east.

(2) The planet having greater longitude and daily motion than those of the Sun, rises in the west.

(3) The planet whose longitude is greater than the longitude of the Sun, and whose daily motion is less than that of the Sun will set in the west.

(4) The planet whose daily motion is greater than that of the Sun and whose longitude is less than that of the Sun will set in the east.

***Śloka* 12** : This *śloka* gives the *kālāṃśa*s of planets.

Table 9.3 : *Kālāṃśas* of planets

Planets	Ca	Ku	Bu	Gu	Śu	Śa	*Va. Bu*	*Va.* Śu
Kālāṃśa	12°	17°	13°	11°	09°	15°	12°	08°

Note : If Budha and Śukra are in retrograde motion (*vakragati*), subtract 1 from their usual (direct motion) *kālāṃśas (as shown in Table 9.3).*

***Śloka* 13** : This *śloka* gives the *pātas* of the five planets (*tārāgrahas*) as below:

Table 9.4 : *Pātas* (Nodes) of Planets

Planets	Budha	Kuja	Guru	Śukra	Śani
Pātāmśa	20°	40°	80°	60°	100°

In the case of Budha and Śukra subtract *śighrakendra* (obtained using *ahargaṇa*) from *patāṃśa* to get the corrected *pātāṃśa*.

***Śloka* 14** : The method of finding *śīghrakarṇa* of planets is explained in this *śloka* as follows :

(1) The six *khaṇḍas* using which we can find *śīghrakarṇa* are:

1, 2, 3, 4, 4, 2.

(2) If the *śīghrakendra* of the planet is greater than 6 *rāśis*, subtract it from 12 *rāśis*.

(3) The number in the *rāśi* position gives the total number of elapsed *khaṇḍas*. Find the sum of all the *gata* (elapsed) *khaṇḍas*.

(4) Now, we have

$$\text{\textit{Śīghrakendraphalam}} = \text{\textit{Sum of the elapsed khaṇḍas}} + \frac{\text{\textit{Eṣyakhaṇḍa}} \times \text{Remainder}}{30}$$

(5) Divide the result of (4) by 1, 2, 4, 1, 7 and subtract the quotients from 18, 15, 13, 19 and 12 respectively. The result gives *śīghrakarṇa* of Kuja, Budha, Guru, Śukra and Śani respectively.

Example : Given date is *Śaka* 1534, *Vaiśākha Śukla Pūrṇimā* (refer to the example under *śloka* 10 in Chapter 3). For the five *tārā grahas* (star-planets) we have their *śīghrakendras* (anomaly of conjunction) as given in Table 9.5.

Table 9.5 *Śīghrakendras* of planets

Planet	*Śīghrakendra*
Kuja	$3^R\ 01°\ 04'\ 57''$
Budha	$1^R\ 16°\ 25'\ 17''$
Guru	$8^R\ 21°\ 20'\ 58''$
Śukra	$3^R\ 04°\ 59'\ 52''$
Śani	$2^R\ 02°\ 50'\ 00''$

The above values are the second *śīghrakendras* while finding the true positions of planets.

(1) To find the *śīghrakarṇa* of Kuja :

Śīghrakendra = $3^R\ 1°\ 4'\ 57''$

(i) In the *rāsi* position, we have 3. This implies that the first three *khaṇḍas* are over.

The elapsed *khaṇḍas* are 1, 2, 3.

(ii) Sum of the elapsed *khaṇḍas* = 6.

(iii) Remainder = $1°\ 4'\ 57''$, *Eṣyakhaṇḍa* = 4

(iv) Sum of the elapsed *khaṇḍas* + $\dfrac{\text{Remainder} \times \textit{Esyakhanda}}{30}$

$$= 6 + \frac{1^\circ\ 4'\ 57'' \times 4}{30} = 6|8|39$$

(v) Dividing by 1 (in the case of Kuja), subtracting the result from 18, we get the *śīghrakarṇa* of Kuja as

$$\textit{Śīghrakarṇa} = 18 - \frac{6|8|39}{1} = 18 - 6|8|39 = 11|51|21$$

(2) To find the *śīghrakarṇa* of Budha :

Śīghrakendra of Budha = $1^R\ 16^\circ\ 25'\ 17''$

Gatakhaṇḍa = 1, *Eṣyakhaṇḍa* = 2, and Remainder = $16^\circ\ 25'\ 17''$

Sum of the *gatakhaṇḍas* + $\dfrac{\textit{Esyakhanda} \times \text{remainder}}{30}$

$$= 1 + \frac{2 \times 16^\circ\ 25'\ 17''}{30} = 2|5|41$$

Dividing the above by 2 and subtracting the resulting quotient from 15 we get the *śīghrakarṇa* of Budha.

i.e., *Śīghrakarṇa* of Budha = $15 - \dfrac{2|5|41}{2} = 13|57|10$

(3) To find the *śīghrakarṇa* of Guru :

Guru's *śīghrakendra* = $8^R\ 21^\circ\ 20'\ 58''$

Śīghrakendra phalam = Sum of the *gatakhaṇḍas* +

$$\frac{\textit{Eṣyakhaṇḍa} \times \text{remainder}}{30} = 7|9|11$$

$$\textit{Śīghrakarṇa} \text{ of Guru} = 13 - \frac{7|9|11}{4} = 11|12|42$$

(4) To find the *śīghrakarṇa* of Śukra :

Śighrakendra = $3^R\ 4°\ 59'\ 52''$

Śīghrakendrāt phalam = 6|39|58

$$\textit{Śīghrakarṇa} \text{ of Śukra} = 19 - \frac{6|39|58}{1} = 12|20|2$$

(5) To find the *śīghrakarṇa* of Śani :

Śīghrakendra = $2^R\ 2°\ 50'\ 0''$

Śīghrakendrāt phalam = 3|17|0

$$\textit{Śīghrakarṇa} = 12 - \frac{3|17|0}{7} = 11|31|52$$

***Śloka* 15** : This *śloka* explain the method of finding the *śara* (latitude) of Kuja, Budha, Guru, Śukra and Śani. It is as follows.

(1) Consider the difference between the *manda* corrected planet and its *pāta*.

(2) Find the declination (*krānti*) of the above result. [Here the *nirayaṇa* planet from which the *pāta* is subtracted has to be considered].

(3) In the case of Budha and Śukra consider

[*Manda* corrected planet – (*Pāta* – *Śīghrakendra*)]

(4) Multiply the declination obtained in step (2) by 23.

(5) Divide the result of step (4) by *śīghrakarṇa*. This gives the *śara* of the planet in *aṅgulas*.

(6) In the case of Kuja, subtract $\frac{1}{4}$ of the *śara* from the *śara* to get the corrected *śara*.

(7) In the case of Guru, divide *śara* (from step 5) by 2 to get the corrected *śara*.

(8) Multiply the *śara* in *aṅgulas* by 3 to get the same in *kalās*. Divide *śara* in *kalās* by 60 to get it in *amśas*.

(9) The *śara* will be north or south according as the (*manda* corrected planet – *pāta*) is in the northern or southern hemisphere.

(10) The declinations of the above planets are to be corrected with their *śaras*.

(1) To find *śara* of Kuja :

Manda corrected Kuja = $10^R\ 3°\ 8'\ 45''$, *Pāta* of Kuja = $1^R\ 10°$

(i) *Manda* corrected Kuja – *Pāta* = $10^R\ 3°\ 8'\ 45'' - 1^R\ 10°$

$$= 8^R\ 23°\ 8'\ 45''$$

(ii) Declination of the above = $23°\ 43'\ 33''$ (south)

(obtained using *Krāntikhaṇḍas* as explained in Chapter 4).

(iii) *Śīghrakarṇa* of Kuja = $11|51|21$

(iv) $23 \times$ (declination) = $23 \times (23|43|33) = 545° \, 41' \, 39''$

(v) $$\acute{s}ara = \frac{545° \, 41' \, 39''}{11|51|21} = 46|1|38 \text{ } a\dot{n}gulas$$

(vi) Corrected *śara* :

Śara obtained = $46|1|38$ *aṅgulas* [in step (v)]

$$\text{Corrected } \acute{s}ara \text{ of Kuja} = \acute{s}ara - \frac{sara}{4}$$

$$= 46|1|38 - \frac{46|1|38}{4} = 34|31|14 \text{ } a\dot{n}gulas \text{ (south)}$$

(2) To find *śara* of Budha :

(i) *Manda* corrected Budha = $1^R \, 5° \, 3' \, 15''$, *Pāta* = $0^R \, 20°$

Śīghrakendra of Budha obtained from *Ahargaṇa* : $1^R \, 17° \, 14' \, 50''$

(ii) Budha – (*Pāta* – *Śīghrakendra*)

$= 1^R \, 5° \, 3' \, 15'' - (0^R \, 20° - 1^R \, 17° \, 14' \, 50'') = 2^R \, 2° \, 18' \, 05''$

(iii) Declination of the above = $21° \, 0' \, 51''$

(iv) $23 \times$ declination $= 21° \, 0' \, 51'' \times 23 = 483|19|33$

(v) *Śīghrakarṇa* of Budha = $13|57|10$ *aṅgulas*

(vi) *Śara* of Budha = $\dfrac{483|19|33}{13|57|10} = 34|38|24$ *aṅgulas* (north)

(3) To find *śara* of Guru :

(i) *Manda* corrected Guru = $4^R\ 12°\ 12'\ 44''$, *Pāta* = $2^R\ 20°$

(ii) Guru – *Pāta* = $1^R\ 22°\ 12'\ 44''$

(iii) Declination of (Guru – *Pāta*) = $18°\ 49'\ 11''$ (north)

(iv) $23 \times 18°\ 49'\ 11'' = 432|51|13$

(v) *Śīghrakarṇa* of Guru = $11|12|42$

(vi) *Śara* of Guru = $\dfrac{432|51|13}{11|12|42} = 38|36|26$

(vii) Corrected *śara* of Guru = $\dfrac{38|36|26}{2} = 19|18|13$ *aṅg.* (north)

(4) To find *śara* of Śukra :

Pāta of Śukra = $2^R\ 0°$

Śīghrakendra of Śukra = $3^R\ 5°\ 41'\ 35''$

Manda corrected Śukra = $1^R\ 5°\ 25'\ 25''$

(i) Śukra – (*Pāta* – *Śīghrakendra*)

$= 1^R\ 5°\ 25'\ 25'' - (2^R - 3^R\ 5°\ 41'\ 35'') = 2^R\ 11°\ 07'\ 0''$

(ii) Declination of the above = $22°\ 32'\ 2''$ (north)

(iii) $23 \times (22°\ 32'\ 2'') = 518|16|46$

(iv) *Śīghrakarṇa* of Śukra = $12|24|2$ *aṅgulas*

(v) *Śara* of Śukra = $\dfrac{518|16|46}{12|24|2} = 41|47|41$ *aṅgulas* (north)

(5) To find *śara* of Śani :

(i) *Manda* corrected Śani = $10^R\ 21°\ 23'\ 42''$

(ii) *Pāta* of Śani = $3^R\ 10°$

(iii) Śani – *Pāta* = $7^R\ 11°\ 23'\ 42''$

(iv) Declination of (Śani – *Pāta*) = $15°\ 31'\ 06''$ (south)

(v) $23 \times (15° \, 31' \, 06'') = 356|55|18$

(vi) *Śīghrakarṇa* = 11|23|18 *aṅgulas*

$$\therefore \quad \textit{Śara} \text{ of Śani} = \frac{356|55|18}{11|23|18} = 31|20|27 \textit{ aṅgulas} \text{ (south)}$$

Table 9.6 gives the *śara* (latitude) of each planet in *aṅgulas* and in degrees (*amśa*), minutes (*kalās*) and seconds (*vikalās*) of arc for the given example.

Table 9.6 : *Śaras* of planets in *aṅgulas* and degrees

Planets	*Śara* (Latitude)				North / South
	Aṅgulas	Deg.	Min.	Sec.	
Kuja	34|31|14	1	43	33	South
Budha	34|38|24	1	43	55	North
Guru	19|18|13	0	57	54	North
Śukra	41|47|41	2	05	23	North
Śani	31|20|27	1	34	01	South

Note :

(1) The *śara* in *aṅgulas* is converted into *kalās* (minutes of arc) by multiplying by 3 and then into degrees on dividing by 60.

(2) The *śara* is north or south according as the (*manda* corrected planet – *pāta*) is less than or greater than 180°.

The true positions and the declinations of the five *tārāgrahas* are shown in Table 9.7.

Table 9.7 : True longitudes, *krāntis* and *śara spaṣṭa krāntis*

Planets	True longitudes	*Krānti* (N/S) (Declination)	*Śara* (Latitude)	*Śara spaṣṭa Krānti*
Kuja	11^R 05° 56′ 04″	2° 21′ 34″ S	1° 43′ 33″ S	4° 05′ 07″ S
Budha	1^R 17° 04′ 0″	21° 32′ 31″ N	1° 43′ 55″ N	23° 16′ 26″ N
Guru	4^R 02° 9′ 45″	14° 59′ 15″ N	0° 57′ 54″ N	15° 57′ 09″ N
Śukra	2^R 12° 15′ 46″	23° 58′ 58″ N	2° 05′ 23″ N	26° 04′ 21″ N
Śani	10^R 26° 42′ 30″	6° 03′ 00″ S	1° 34′ 01″ S	7° 37′ 01″ S

In the above table, to the right of the column headed by *krānti* (declination), we have the *śara* and the *śara* corrected declination, called (*śara*) *spaṣṭa krānti*, tabulated for all the five "star planets" in two columns. This is obtained for each planet by taking the algebraic sum of its latitude and declination. That is, (i) if the latitude (*śara*) and declination (*krānti*) are in the same direction, then the sum of their numerical values is taken and the direction is the same as their common direction; (ii) if the *śara* and *krānti* are in opposite directions, then the difference of their numerical values is taken and the direction is that of the higher numerical value.

***Śloka* 16** : Now obtaining, from the *pañcāṅga*, the *manda* corrected planets for the purpose of determing the *śara* (latitude) is explained.

On the day on which a planet retrogrades or rises or sets, according to the *pañcāṅga* (traditional ephemeris or almanac),the *śīghrakendra* of that planet can be known.

The *śīghrakendra* and the true longitude of the planet for the given time are determined using their respective rates of motion. By finding the *śīghraphalam*, from the *śīghrakendra*, and applying this to the true position in the reverse process, the *manda* corrected planet can be obtained, Then from this the *śara* is determined as explained earlier (in *śloka* 15).

***Śloka* 17** : This *śloka* gives the *natāṃśa* of planets, as follows :

(i) If the planet rises or sets in the east, subtact 3 *rāśis* from the true postion, of the planet and find its declination (*krānti*).

(ii) If the planet rises or sets in the west, add 3 *rāśis* to the true position and find the declination of the sum.

(iii) The *natāṃśa* = *krānti* ± *akṣāṃśa* $\equiv \delta - \phi$

where δ and ϕ are respectively the declination and the latitude of the planet.

Example :

True Śukra = $11^R\ 13^\circ\ 14'\ 29''$

Since Śukra sets in the east, subtract 3 *rāśis* from it.

i.e., $11^R\ 13^\circ\ 14'\ 29'' - 3^R = 8^R\ 13^\circ\ 14'\ 29''$.

The declination (*krānti*) of the above $\delta = 23^\circ\ 55'\ 42''$ South.

Natāṃśa = *krānti* ± *akṣāṃśa* = $\delta - \phi$ = $49^\circ\ 23'\ 24''$ South

Here, the latitude of the place $\phi = 25^\circ\ 27'\ 42''$ (N) i.e. of Kāśī.

***Śloka* 18** : This *śloka* explains the method of finding *dṛkkarma* correction using *khaṇḍas* as follows :

(i) The *dṛkkarma khaṇḍas* are 6, 7, 8, 9, 12 and 18.

(ii) Divide *natāmśa* by 10. The quotient gives the number of elapsed *khaṇḍas*.

(iii) Consider the product of remainder in (ii) and *eṣyakhaṇḍa* (*khaṇḍa* to be covered). Divide the product by 10.

(iv) Add the sum of elapsed *khaṇḍas* to the result of step (iii).

(v) Mutiply the above result by *śara* and divide the product by 12. The result will be in *kalās* and is called *dṛkkarma phala*.

(vi) The *dṛkkarma phala* is additive if *śara* and *natāmśa* are in the same direction and it is subtractive if *śara* and *natāmśa* are in different directions. This convention is followed in the case of *pūrvodayāsta* (i.e., setting and rising in the east). For *paścimodayāsta* (i.e., rising and setting in the west) consider the reverse operation.

Example :

(i) *Natāṃśa* = $49° \, 23' \, 24''$ for Śukra (see example under *śloka* 17).

We have $\dfrac{Nat\bar{a}\dot{m}\acute{s}a}{10} = \dfrac{49° \, 23' \, 24''}{10} = 4 + \dfrac{9° \, 23' \, 24''}{10°}$

Here, quotient = 4 and remainder = $9° \, 23' \, 24''$

The number of *gata* (elapsed) *khaṇḍas* = 4

They are 6, 7, 8, 9.

Sum of these *khaṇḍas* = 6 + 7 + 8 + 9 = 30°

Eṣyakhaṇḍa = 12

(ii) Now, $\dfrac{E\d{s}yakha\d{n}\d{d}a \times \text{Remainder}}{10}$ + Sum of *gata khaṇḍas*

$$= \frac{12 \times 9° \, 23' \, 24''}{10} + 30° = 41° \, 16' \, 14''$$

(iii) *Śara* = 30|12|15 *aṅgulas* (South)

$\therefore$ *Śara* $\times 41° 16' 14'' = 30|12|15 \times 41|16|14 = 1246|20|29$

$$\therefore \textit{Dṛkkarma} = \frac{1246|20|29}{12} = 103' 51'' = 1° 43' 51''$$

Since *natāṃśa* and *śara* are in the same direction (south), the *dṛkkarma* is additive.

(iv) Now, therefore, the *dṛkkarma* corrected *Śukra* = True *Śukra* + *dṛkkarma*

$$= 11^R 13° 14' 29'' + 1° 43' 51'' = 11^R 14° 58' 20''$$

***Śloka* 19** : This *śloka* explains about the time (*kālāṃśa*) of setting and rising of a planet.

(1) Consider Ravi and the *dṛkkarma* corrected planet. Between these two, the one having lesser longitude is to be treated as Ravi and the one with greater longitude as *Lagna*.

(2) Add *ayanāṃśa* to both Ravi and *lagna* (thus considered).

The time interval between these in *ghaṭikās* (from the *udayakālas* of the intervening *rāśis* and the elapsed portions of the *rāśis*) is determined. This on multiplying with 6 gives the *antarāṃśas* i.e., the difference in degrees. If the *antarāṃśa* is greater than the *kālāṃśa* mentioned earlier for the planet, the *setting* of the planet is yet to take place. On the other hand, if the *antarāṃśa* is less than the *kālāṃśa*, then the planet has already set.

Similarly, in the case of *rising* (*udaya*) of the planet, the reverse is the case.

Example : True Ravi = $11^R 23° 32' 26''$

Dṛkkarma corrected *Śukra* = $11^R 14° 58' 20''$

Ayanāṃśa = $18^\circ\ 08'$

Since, of the above two bodies, Śukra is less than Ravi, Śukra is to be treated as Ravi and (the actual) Ravi as Lagna. i.e., now, the changed

(*Sāyana*) Ravi = $0^R\ 3^\circ\ 6'\ 20''$ and (*Sāyana*) Lagna = $0^R\ 11^\circ\ 40'\ 26''$

The difference between them = $0^R\ 8^\circ\ 34'\ 06''$

Since both are in *Meṣa rāśi* and the *udayamāna* of *Meṣa* is 221 *vig.* for

Kāśī, the time interval = $\dfrac{8^\circ\ 34'\ 06''}{30^\circ} \times 221$ *vig.* = $1^{gh.}\ 03^{vig.}$

$\therefore$ *Antarāṃśas* = $1^{gh.}\ 03^{vig.} \times 6 = 6^\circ\ 18'$

Since the *antarāṃśa* of Śukra is less than its corrected *kālāṃśa* ($6^\circ\ 46'$) the planet has already set. *Antarāṃśa* is also referred to as *Iṣṭa kālāṃśa.*

***Śloka* 20** : This *śloka* explains the method of finding the day of the *udaya* (rising) and the *asta* (setting). It is as follows.

(i) Consider the difference between the *iṣṭa kālāṃśa* (obtained in the previous *śloka*) and the corrected *kālāṃśa*. Express the difference in *kalās*.

(ii) Multiply the above difference by 300.

(iii) Divide the result of step (ii) by *udayamāna* of the *rāśi* in which Ravi is present (Ravi *rāśi*).

(iv) Divide the above result by the difference between the daily motion of the Sun and that of the planet whose *udayāsta* is to be determined. This gives the day of *udayāsta*. This is in the case of *pūrvodayāsta*. (i.e., for planets rising and setting in the east).

(v) For the planets rising and setting in the west (i.e., *paścimodayāsta*), proceed upto step (ii) as explained above. Divide the result of step (ii) by the *udayamāna* of the 7th *rāśi* of *sāyana* Ravi (i.e., 180° from the *sāyana* Ravi).

(vi) If the planet is in retrograde motion, then consider the sum of the motion of the planet and that of he Sun in step (iv).

Example : Corrected *kālaṃśa* = $6^\circ\ 46'$ (explained later in *Śloka* 21).

Iṣṭa kālāṃśa = $6^\circ\ 18'$ (obtained from the previous *śloka*)

(i) The difference = $6^\circ 46' - 6^\circ 18' = 0^\circ\ 28' = 28'$

Here we consider Śukra which rises and sets in the *east*.

(ii) *Udayamāna* of Rāvi *raśi* = $221^{vig.}$ (i.e., of *Meṣa*)

(iii) Multiplying the result of (i) by 300 and dividing by that of (ii)

we have $\dfrac{28 \times 300}{221} = 38|0|32$

(iv) Difference between the motions of Śukra and the Sun = $15'\ 53''$

Now, $\dfrac{38|0|32}{15|53} = 2^{d}\ 23^{gh}\ 34^{vig}$

Therefore, $2^{d}\ 23^{gh}\ 34^{vig}$ before the given date viz. *Caitra Śukla Aṣṭamī* Śukra had set.

***Śloka* 21** : The correction for the *kālāṃśas* for the rising and setting of the Moon and Śukra is explained.

The difference between 300 and the *udayamāna* (in *vighaṭīs*) of the *rāśi* of the *sāyana* planet (the Moon or Śukra) divided by 27. The result will be in *aṃśas* (degrees) etc. and it is additive or subtractive according as the *udayamāna* is greater than or less than 300 *vig.* i.e., (*Udayamāna* -300) is positive or negative. The result is accordingly added to or subtracted from *dṛkkarma phalam* of the planet. If both are of the same sign then take the sum of their numerical values (and attach their common sign). If they are of opposite signs, the difference of their numerical values is taken (and the sign of the bigger number is attached). In other words, consider their algebraic sum.

Then $\frac{1}{5}$th of the above result is accordingly added to or subtracted from the prescribed *kālāṃśas* of the planet (viz., 12° and 9° respectively for the Moon and Śukra).

In the case of Śukra subtract 2° from the above result. This gives the corrected *kālāṃśa*.

Example : *Sāyana* Śukra = $0^R\ 3^\circ\ 06'\ 20''$

(i) *Dṛkkarma phala* = $+1^\circ\ 43'\ 51''$

Śukra is in *Meṣa rāśi* and its *udayamāna* is 221 *vig.* (for *Kāśī*)

(ii) Now, $\dfrac{221-300}{27} = -2^\circ\ 55'\ 33''$

iii) The algebraic sum of (i) and (iii) is $-1^\circ\ 11'\ 42''$.

iv) $\frac{1}{5}$th of the result of (iii) is $\frac{1}{5} \times (-1^\circ\ 11'\ 42'') \approx -0^\circ\ 14'$

v) The prescribed *kālāṃśa* of Śukra = 9°.

Combining the results of (iv) and (v) and subtracting 2° (for Śukra) we get

Corrected *kālāṃśa* $= (9^\circ - 0^\circ\,14') - 2^\circ = 6^\circ\,46'$.

***Śloka* 22** : Now, the rising and setting timings of the *Agastya* star (Canopus) are explained.

Multiply the *palabhā* by 8 and subtract from and add to 78° and 98° respectively. These values correspond respectively to the setting and rising of the *Agastya* star after those of the Sun.

Example : *Palabhā* = $5|45$ *aṅgulas* (for Kāśī)

We have

(i) $78^\circ - 8 \times$ *palabhā* $= 32^\circ \equiv 1^R\,2^\circ$ i.e., *Vṛṣabha rāśi* 2°.

This corresponds to the *setting* of the *Agastya* star.

(ii) $98^\circ + 8 \times$ *palabhā* $= 144^\circ \equiv 4^R\,24^\circ$

i.e., *Siṃha* 24° corresponding to the rising of the *Agastya* star. This means that the *Agastya* star sets when the Sun reaches *Vṛṣabha* 2° and rises when the Sun is at *Siṃha* 24°.

Remark : The commentator gives the following explanation for the constants used in the above method.

According to the procedure given by Bhāskara II, at a place whose *palabhā* (or *akṣabhā*) is 1 *aṅgula*, the *dṛkkarma* = 8°. Therefore, by the rule of three, if the *palabhā* of a place is x *aṅg.* then the *dṛkkarma* = $8x$ degrees.

The *āyana dṛkkarma* corrected *udaya dhruvaka* (longitude) of the *Agastya* star is 87° (i.e., for the rising). For this the *kālāṃśa* is 12° and the *kṣetrāṃśa* is 11°. The *asta dhruvaka* (i.e., for setting) after the *āyana dṛkkarma* correction is 89°. Therefore, adding and subtracting 11° respectively to the two *dhruvakas* we get 98° and 78° for the setting and rising of *Agastya*.

Śloka 23 : This *śloka* explains the daily setting and rising of a planet.

(1) Find the true longitude of the Sun and the planet at the time of the sunset.

(2) If the planet is greater than the *saṣaḍbha Sūrya* (i.e., true Sun + 6^R) or less than the true Sun, then it rises in the night.

(3) Otherwise, i.e., if the planet is less than *saṣaḍbha Sūrya* and greater than the Sun then it sets in the night.

(4) Obtain the *dṛkkarma* corrected planet to find the time or *lagna* of rising and setting. Find *pūrva dṛkkarma* for rising and *paścima dṛkkarma* for setting.

Example : *Śaka* = 1534, *Vaiśākha śukla* 15 (*Pūrṇimā*)

To find daily setting and rising of Guru we have the following :

True Sun = $1^R\ 5^\circ\ 42'\ 37''$, True daily motion of the Sun = $57'\ 36''$

True Guru = $4^R\ 2^\circ\ 9'\ 49''$, True daily motion of Guru = $5'\ 22''$

Dinamānam = $33|6$ *ghaṭīs*

Sun at the sunset = $1^R\ 6^\circ\ 14'\ 13''$

True Guru at the sunset = $4^R\ 2°\ 12'\ 46''$

Now, the Sun + 6^R i.e., *saṣaḍbha Sūrya* = $7^R\ 5°\ 42'\ 37''$ is greater than Guru and Guru = $4^R\ 2°\ 12'\ 46''$ is greater than the Sun. Therefore Guru sets in the night [from condition (3) above].

To find *paścima dṛkkarma* :

Guru + 3^R = $7^R\ 2°\ 12'\ 46''$, *Krānti* = $18°\ 12'\ 41''$ (South)

Natāṃśa = $43°\ 38'\ 23''$ (South), *Dṛkkarma* = $55'\ 18''$

Dṛkkarma corrected Guru = $4^R\ 3°\ 08'\ 04''$

***Śloka* 24** : Now, the *rātri* (night) *ghaṭīs* of *udaya* (rising) and *asta* (setting) of a planet is explained.

For the rising and the setting of a planet, the corrected true longitude and the same *plus* 6 *rāśis* respectively are considered. Find the *bhukta kāla* (elapsed time) of the above. To this add the *bhogya kāla* (balance time) of 6 *rāśis* plus true Ravi. Add the *udayamānas* of the *rāśis* lying between the relevant value of the planet and (6^R + Ravi). Divide this by 60 to get the *rātri gata kāla*. This is corrected by considering the true positions (in degrees etc.).

Example : At the sunset we have

Dṛkkarma corrected Guru = $4^R\ 3°\ 08'\ 04''$.

6 *rāśis* + *nirayaṇa* Guru = $10^R\ 3°\ 08'\ 04''$

Bhuktakāla of the *sāyana* of the above = 179 *vighaṭīs*

6 *rāśis* + *nirayaṇa* Ravi = $7^R\ 6°\ 14'\ 23''$

Bhogyakāla of the *sāyana* of the above = 64 *vig.*

Intervening *rāśis* are *Dhanus* and *Makara*. Their *udayamānas* are 342 *vig.* and 304 *vig.*

Sum of these *kālas* (time intervals) = 179 + 64 + 342 + 304 = 889 *vig.*

Dividing this sum by 60, we get $889\ vig./60 = 14^{gh.}\ 49^{vig.}$

Thus, Guru sets at $14^{gh.}\ 49^{vig.}$ after the sunset.

To obtain the corrected (*spaṣṭīkṛta*) instant :

At $14^{gh.}\ 49^{vig.}$ (after sunset) Guru = $4^R\ 2°\ 14'\ 06''$

At that instant, Ravi = $1^R\ 6°\ 28'\ 46''$

Lagna *bhukta kāla* = 179 *vig.*, Ravi *bhogyakāla* = 61|36|06 *vig.*

Udayamānas of *Dhanu* and *Makara* are respectively 342 and 302 *vighaṭīs*.

Adding these timings, we get 886 *vig.* Dividing by 60, we get $14^{gh.}\ 46^{vig.}$.

***Śloka* 25** : A special correction for the instants of the Moon's rising and setting is explained.

Respectively add to and subtract from the timings of *udaya* and *asta* of the Moon 9 *palas* (*vighaṭīs*). Then add (in both cases) 2 *palas* (*vig.*) for each *ghaṭī* thus obtained. These values give the corrected instants of the Moon's rising and setting. In this case there is no need of obtaining the true Moon at the particular instants.

CHAPTER 10

GRAHACCHĀYĀDHIKĀRAḤ

(Planetary Shadows)

The visibility or otherwise of a planet in the night and obtaining *dinagata kāla* and shadow of a planet are explained.

***Śloka* 1** : From this *śloka* we find the *dinagatakāla* of the planets and the Moon as follows.

(1) If the *dṛkkarma* corrected planet at sunrise is less than the *iṣṭakāla lagna* (i.e., *lagna* at a given time) and if it is greater than the *saptama lagna*, then the planet is visible at the *iṣṭakāla*.

(2) Adding the *bhuktakāla* of *lagna* and the *udayamānas* of the *madhyagata* (intervening) *rāśis* to the *bhogyakāla* of the planet, we get *dinagatakāla* of the planet.

(3) In the case of Moon, subtract 9 *palas* from its *dinagatakāla* to get the corrected *dinagatakāla* of the Moon.

Example : Given date is May 1, 1610 A.D. (*G*) :

> *Śaka* 1532, *Vaiśākha Śukla navamī* (9), Saturday.
>
> *Cakra* = 8 and *Ahargaṇa* = 777
>
> *Rātrighaṭīs* = 10 *gh.* (*iṣṭakāla*)

Mean positions of the Sun, the Moon, Moon's *mandocca* and Rāhu for the given date, at the mean sunrise, are as follows :

Sun = $0^R\ 20°\ 56'\ 22''$, Moon = $3^R\ 26°\ 58'\ 3''$

Moon's *uccam* = $7^R\ 22°\ 04'\ 6''$, Rāhu = $2^R\ 23°\ 47'\ 3''$

Now, *Ayanāṃśa* = $18°\ 08'$, *Cara* = $-73''$

Manda corrected Ravi = $0^R\ 22°\ 46'\ 02''$

Cara corrected Ravi = $0^R\ 22°\ 44'\ 49''$

True daily motion of the Sun = $59'\ 58''$

Manda corrected true Moon = $4^R\ 1°\ 7'\ 13''$

True daily motion of the Moon = $719'\ 19''$

Dinamānam = $32^{gh}\ 26^{vig}$

Since the given time is *rātrighaṭīs* 10 *gh*. (*iṣṭakāla*),

the time from sunrise = $32^{gh}\ 26^{vig} + 10^{gh} = 42^{gh}\ 26^{vig}$.

At this instant, we have

True Sun = $23°\ 25'\ 48''$, True Moon = $4^R\ 10°\ 46'\ 39''$

Rāhu = $2^R 23° 44' 48''$

Now, Moon – Rāhu = $1^R 17° 01' 51''$ *Śara* = 65|44 *aṅgulas*

Moon – 3 *rāśis* = (*tribha-varjita-Candra*)

$$= 4^R\, 10°\, 46'\, 39'' - 3^R = 1^R\, 10°\, 46'\, 39''$$

Declination of the above, $\delta = 20°\, 19'\, 39''$ (north)

Akṣāṃśa $\phi = 25°\, 26'\, 42''$ (north) for Kāśī

Natāṃśa = $(\delta - \phi) = -5°\, 7'\, 3''$

Dṛkkarma = $-16'\, 49''$

Dṛkkarma corrected Moon = $4^R\, 10°\, 29'\, 50''$

Rātrigata ghaṭīs = 10^{gh} (given time)

(*Nirayaṇa*) *Lagna* = $8^R\, 16°\, 24'\, 22''$

(*Nirayana*) *Asta Lagna* = $2^R\, 16°\, 24'\, 22''$ (by adding 6^R)

We note that the *sāyana dṛkkarma* corrected Moon is in the *Simha rāśi*, and the *sāyana lagna* is in the *Makara rāśi*.

Sum of the rising durations (*udayamānas*) of intervening *rāśis* from *Kanyā* to *Dhanus* = 1357 *vig.*

Remark : For the town of *Kāśī*, the rising durations (*udayamānas*) for *Siṃha, Kanyā, Tulā, Vṛṣcika, Dhanus* and *Makara* are respectively 345, 335, 335, 345, 342 and 304 *vighaṭīs*. However, considering the four *rāśis* in between *Siṃha* and *Makara* the sum of the *udayamānas* is 335 + 335 + 345 + 342 = 1357 *vighaṭīs* (i.e., of *Kanya, Tulā, Vṛścika* and *Dhanus*).

Bhukta kāla of Sāyana lagna :

Nirayana lagna : $8^R\ 16°\ 24'\ 22''$, *Ayanāṃśa* = $18°\ 08'$

∴ *Sāyana lagna* : $9^R\ 4°\ 32'\ 22''$

i.e., *Bhuktāṃśas* = $4°\ 32'\ 22''$ in (*sāyana*) *Makara*

$$\therefore \quad \textit{Bhukta kāla} = \frac{4°\ 32'\ 22''}{30°} \times 304\ \textit{vig.} = 46\ \textit{vig.}$$

Bhogyāṃśas of *Sāyana dṛkkarma* corrected Moon = $5^R - (4^R\ 28°\ 37')$

= $1°\ 23'$ in *Sāyana Siṃha*

$$\therefore \quad \textit{Bhogyakāla} = \frac{1°\ 23'}{30°} \times 345\ \textit{vig.} \approx 15.90\ \textit{vig.} \approx 16\ \textit{vig.}$$

Their sum = $46^{vig.} + 16^{vig.} = 62^{vig.}$

Now, the sum of the *udayamānas* and the above result

$$= (1357 + 62)^{vig.} = 1419\ vig.$$

Dividing this by 60, we get the *dinagatakāla* of the Moon (in *ghaṭīs*)

i.e., $\textit{dinagatakāla} = \frac{1419}{60}\ gh. = 23^{gh.}\ 39^{vig.}$

For the Moon, subtract 9 *palas* from the above result,

i.e., *dinagatakāla* of the Moon = $23|39\ gh. - 0|9\ gh. = 23|30\ gh.$

from the sunrise.

Śloka 2 : This *śloka* explains the method of finding *grahacchāyā* (planet shadow) as follows :

(1) Multiply *śara* (in *aṅgulas*) by the *palabhā* of the place.

(2) Divide the product by 24.

(3) The above result is added to or subtracted from the *cara* to get *spaṣṭa cara* (corrected *cara*)

i.e., Corrected *cara* = $cara \pm \left(\dfrac{śara \times palabh\bar{a}}{24} \right)$

(4) Obtain the *dinamānam* (duration of the day) from the corrected *cara*.

(5) Obtain the *chāyā* of the planet from *dinagatakāla*.

Example : *Cara* obtained from *dṛkkarma* corrected Moon = $59''$ (northern).

$$Śara = 65|44 \text{ aṅgulas} ; Palabh\bar{a} = 5|45 \text{ aṅg.}$$

$$\therefore \quad \text{Corrected } Cara = Cara + \frac{śara \times palabh\bar{a}}{24}$$

$$= 59 + 15|44 = 74|44 \text{ vig.} = 1^{gh}\, 14^{vig}\, 44^{pv.}$$

$$Dinam\bar{a}nam = 32^{gh}\, 28^{vig}$$

Note : *Dinamānam* = 2 × [Mean *dinārdha* + Cor. *Cara*)

$$= 2 \times [15^{gh.} + 1^{gh.}\, 14^{vig.}\, 44^{pv.}] \approx 32^{gh}\, 29^{vig}$$

Dinagata kāla of the Moon = $23^{gh}\, 29^{vig}$ (obtained from *Śloka* 1).

Dinamānam – *Dinagata kāla* = $32^{gh}\ 29^{vig} - 23^{gh}\ 29^{vig} = 9^{gh}$

Paścima natam = $7^{gh}\ 15^{vig}$

Akṣakarṇa = $\sqrt{(\acute{s}a\dot{n}ku)^2 + (Palabh\bar{a})^2}$

$= \sqrt{(12)^2 + (5|45)^2} = 13|18$ *aṅgulas*

Hāra = $128|56$, *Samākhya* = $30|01$, *Abhimatahāra* = $7|25$

Bhājya = $117|55$, *Karṇa* = $15|53$ *aṅgulas*

Iṣṭachhāyā = $10|24$ *aṅgulas*

Śloka 3 : Finding the *chāyā* of a planet using *dhīyantra* is explained. The reflection of the planet is first seen in water. The *lamba* is measured from the (horizontal) ground level to the point of reflection. The distance between the foot of the *lamba* and the point of reflection is measured in *aṅgulas*. This will be the *bhuja*. This value is multiplied by 12 and divided by the elevation (height) of the reflected point. The result gives the *chāyā* of the planet in *aṅgulas*.

From the similar triangles *ABD* and *RMD*, in Fig. 10.1 we have

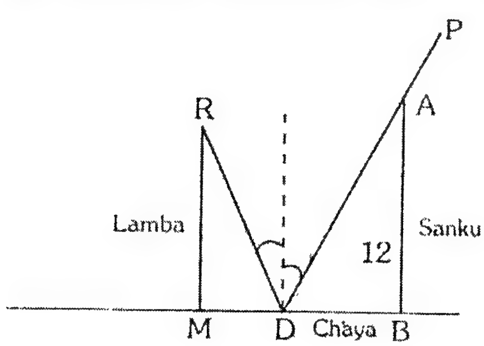

Fig. 10.1 *Grahacchāyā*

Chāyā $DB = \dfrac{MD}{MR} \times 12$ aṅgulas

Śloka 4 : Now, the obtaining of *dinagata kāḷa* from a planet's *chāyā* (shadow) is explained. Knowing the time in the night, find the then position of the planet and hence *cara*. Using the *cara* and *chāyā*, the *dinagata kāla* of the planet is determined just as in the case of the Sun as explained in *tripraśnādhikāra*. In the case of the Moon, 9 *palas* is added to the result.

Example : We have the given time (*iṣṭakāla*) :

Ratrigata ghaṭikā (time in the night) = 10 *gh.* (after sunset)

Cara = $74|44$,*Dinamānam* = $32|28$ *gh.* *Iṣṭacchāyā* = $10|24$ *aṅg.*

Karṇa = $15|53$, *Bhājya* = $117|55$, *Hāra* = $7|25$

Akṣakarṇa = $13|18$ *aṅg.* *Madhyahara* = $128|56$

Natam = $7|15$ (West), *Dinārdham* = $16|14$ *gh.*

Dinagatakāla of the planet = *Natam* + *Dinārdham*

= $(7|15 + 16|14)$ *gh.* = $23|29$ *gh.*

Dinagatakāla of the Moon = $(23|29 + 0|9)$ *gh.* = $23|38$ *gh.*

Śloka 5 : Between the *dṛkkarma* corrected planet and the Sun *plus* six *rāśis* whichever is less is treated as the Sun and the other as the *lagna*. The *antarāṃśa ghaṭī* is determined by the process explained earlier. According as the (*dṛkkarma*) corrected planet is less than or greater than the Sun *plus* six *rāśis*, the *antarāṃśa ghaṭī* will be *dina śeṣa ghaṭī* (the balance *ghaṭī* of the day time) or *rātrī gata ghatī* (the elapsed *ghaṭī* in the night i.e., after the sunset).

Example : *Dṛkkarma* corrected Candra = $4^R\ 10°\ 29'\ 50''$. Sun + 6 *rāśis* = $6^R\ 23°\ 25'\ 48''$ (*nirayaṇa*). Between these, Candra is less. Therefore Candra is to be considered as the Sun and the other value viz. $6^R\ 23°\ 25'\ 48''$ as of the *Lagna*.

We shall find the *antarāṃśa ghaṭīs*. We have *ayanāṃśa* = $18°\ 10'$. *Sāyana* Candra (to be considered as the Sun) = $4^R\ 10°\ 29'\ 50'' + 18°\ 10'$ = $4^R\ 28°\ 39'\ 50''$. *Sāyana* Sun + 6 *rāśis* = $6^R\ 23°\ 25'\ 48'' + 18°\ 10'$ = $7^R\ 11°\ 35'\ 48''$. Therefore, we have *Arkabhogya* = $30° - 28°\ 39'\ 50'' = 1°\ 20'\ 10''$ in *Siṃha rāśi* whose *udayamāna* = 345 *vig.* Therefore, we have

$$Arkabhogya\ ghaṭīis = \frac{1°\ 20'\ 10''}{30°} \times 345\ vig. \approx 15\ vig.$$

Tanu bhukta bhāga (i.e., elapsed degrees in the *sāyana Lagna*) = $11°\ 35'\ 48''$ in *Vṛścika*. Therefore, we have

$$Tanu\ bhukta\ ghaṭī = \frac{11°\ 35'\ 48''}{30°} \times 345\ vig. \approx 133\ vig.$$

(noting that the *udayamāna* of *Vṛścika* = 345 *vig.*)
In between these, the completed *rāśis* risen = *Kanyā* 335 *vig.* + *Tulā* 335 *vig.* = 670 *vig.* Therefore,

$$Antarāṃśa\ ghaṭīs = \frac{(15+133+670)}{60}\ vig. = \frac{818}{60}\ gh. = 13^{gh.}\ 38^{vig.}.$$

Since *Candra* < (Sun + 6^R), *dina śeṣa kāla* = $13^{gh.}\ 38^{vig.}$.

***Śloka* 6** : By adding to or subtracting from the *dina gata kāla* of a planet the *dinaśeṣa* or *rātrigata kāla* respectively, we get the *rātri gata kāla* (i.e., time after the sunset). In the case of the Moon, if the obtained time is less than or greater than the guessed time (*anumita kāla*), then accordingly the difference multiplied by 2 in *palās* is added to or subtracted from the obtained time to get the correct time.

Example : *Dinagatakāla* of the Moon = $23^{gh.}\ 38^{vig.}$ (see example under *Śloka* 4). *Dina śeṣa kāla* = $13^{gh.}\ 38^{vig.}$ (obtained under *Śloka* 5). Subtracting the latter from the former, we get $23^{gh.}\ 38^{vig.} - 13^{gh.}\ 38^{vig.} = 10^{gh.}$. This is the *rātri ghaṭī* after the sunset (see example under *Śloka* 1).

CHAPTER 11

NAKṢATRA CHĀYĀ

(Shadow of Stars)

In this chapter the shadow of stars is discussed.

***Ślokas* 1 and 2** : The *āyana dṛkkarma* corrected *dhruvas* (polar longitudes) of the *nakṣatras* (junction stars or *yogatārās*) from *Aśvinī* onwards are (in degrees) respectively 8, 21, 38, 49, 62, 66, 94, 106, 107, 129, 148, 155, 160, 183, 198, 212, 224, 230, 242, 255, 261, 258, 275, 286, 320, 325, 337, 0. Dividing these by 30 we get them in *rāśi* etc. The 28 *yogatārās* include *Abhijit* and their *dhruvas* are shown in Table 11.1.

Multiply the *śara* (celestial latitude of the junction star given in the next *śloka*) by the *palabhā* (equinoctial shadow of the gnomon) and divide by 12. The result is added to or subtracted from the *dhruvas* given above (to get those for the given place). When the *śara* is south then the above result is added to or subtracted from the above given *dhruvas* according as those are eastern or western. If the *śara* is north then the addition and subtraction are reversed.

***Śloka* 3** : The *śaras* (cel. latitude) of the 13 *yogatārās* from *Aśvinī* to *Hasta* are 10, 12, 5, 5, 10, 11, 6, 0, 7, 0, 12, 13 and 11. Those of the next nine *nakṣatras* from *Citrā* to *Abhijit* are 2, 37, 1, 2, 3, 8, 5, 5, 62. The *śaras* of the remaining six *nakṣatras* from *Śravaṇa* to *Revatī* are 30, 6, 3, 0, 24, 0.

Among these *Citrā*, *Hasta*, *Āśleṣā* and 6 *nakṣatras* from *Viśākhā*, the 3 from *Rohiṇī* and *Śatabhiṣaj* have their *śara* (latitude) south. The remaining 15 *nakṣatras* have their *śara* north.

Table 11.1 *Nakṣatras* with their *Dhruvas* and *Śaras*

No.	*Nakṣatra Yogatāra*	*Dhruva* (Degrees)	*Śara* (Degrees)
1.	*Aśvinī*	8	10
2.	*Bharaṇī*	21	12
3.	*Kṛttikā*	38	5
4.	*Rohiṇī*	49	– 5
5.	*Mṛgaśira*	62	– 10
6.	*Ārdrā*	66	– 11
7.	*Punarvasu*	94	6
8.	*Puṣya*	106	0
9.	*Āśleṣā*	107	– 7
10.	*Makhā (or Maghā)*	129	0
11.	*Pubba (Pūrva Phālguni)*	148	12
12.	*Uttarā (Uttara Phālguni)*	155	13
13.	*Hasta*	160	– 11
14.	*Cittā (or Citrā)*	183	– 2
15.	*Svātī*	198	37
16.	*Viśākhā*	212	– 1
17.	*Anurādhā*	224	– 2
18.	*Jyeṣṭhā*	230	– 3
19.	*Mūlā*	242	– 8
20.	*Pūrvāṣādhā*	255	– 5
21.	*Uttarāṣādhā*	261	– 5
22.	*Abhijit*	258	62
23.	*Śravaṇa*	275	30
24.	*Dhaniṣṭhā*	286	6
25.	*Śatabhiṣaj*	320	– 3
26.	*Pūrvābhādrā*	325	0
27.	*Uttarābhādrā*	337	24
28.	*Revatī*	0	0
29.	*Prajāpati*	61	39
30.	*Brahmahṛdaya*	56	30
31.	*Agni*	53	8
32.	*Agastya*	88	– 76
33.	*Apāmvatsa*	183	3
34.	*Lubdhaka*	81	– 40

Ślokas **4 and 5** : The *dhruvāṃśas* of *Prajāpati, Brahmahṛdaya, Agni, Agastya, Apāmvatsa* and *Lubdhaka* are respectively 61, 56, 53, 88, 183, 81. The *śarāṃśa* of these are respectively 39, 30, 8, 76, 3, 40. Among these, *Agastya* and *Lubdhaka* have their *śara* south. The remaining are in the nothern hemisphere.

Table 11.1 lists the *nakṣatras* with their *dhruvas* and *śaras*. Table 11.2 gives the list of the 27 *nakṣatras*, in their natural order, and their angular extents. Each *nakṣatra* was named after the most prominently visible star (called *yogatārā* or junciton-star) contained within its range, given in Table 11.2. The *yogatārās* with modern equivalents and their co-ordinates are listed in Table 11.3 (reproduced from *Lahiri's Indian Ephemeris* for 1995).

Table 11.2 *Nakṣatras* and their range of *nirayaṇa* longitudes

No.	*Nakṣatra*	From	To
1.	*Aśvinī*	0°0′	13°20′
2.	*Bharaṇī*	13°20′	26°40′
3.	*Kṛttikā*	26°40′	40°00′
4.	*Rohiṇī*	40°00′	53°20′
5.	*Mṛgaśira*	53°20′	66°40′
6.	*Ārdrā*	66°40′	80°00′
7.	*Punarvasu*	80°00′	93°20′
8.	*Puṣya*	93°20′	106°40′
9.	*Āśleṣā*	106°40′	120°00′
10.	*Makhā* (or *Maghā*)	120°00′	133°20′
11.	*Pubba* (*Pūrva Phālguṇī*)	133°20′	146°40′
12.	*Uttarā (Uttara Phālguṇī)*	146°40′	160°00′

Table 11.2 (continued)

No.	*Nakṣatra*	From	To
13.	*Hasta*	160°00′	173°20′
14.	*Cittā (or Citrā)*	173°20′	186°40′
15.	*Svātī*	186°40′	200°00′
16.	*Viśākhā*	200°00′	213°20′
17.	*Anurādhā*	213°20′	226°40′
18.	*Jyeṣṭhā*	226°40′	240°00′
19.	*Mūlā*	240°00′	253°20′
20.	*Pūrvāṣādhā*	253°20′	266°40′
21.	*Uttarāṣādhā*	266°40′	280°20′
22.	*Śravaṇa*	280°20′	293°20′
23.	*Dhaniṣthā*	293°20′	306°40′
24.	*Śatabiṣaj*	306°40′	320°00′
25.	*Pūrvābhādrā*	320°00′	333°20′
26.	*Uttarābhādrā*	333°20′	346°40′
27.	*Revatī*	346°40′	360°00′

Table 11.3 *Mean places* of stars for 1995.0

(i.e., on Jan. 0.822 UT = Jan. 0.25h 14m IST)

Note : Tropical or *Sāyana* long. = *Nirayaṇa* long. + 23° 47′ 14″.1 *ayanāṃśa*

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
β Arietis	*Aśvinī*	2.72	0	10	06	46	+8	29	14	1	54	21.8	+20	47	01
α Arietis	...	2.23	0	13	48	19	+9	57	54	2	06	53.4	+23	26	20
41 Arietis	*Bharaṇī*	3.68	0	24	20	48	+10	26	58	2	49	41.3	+27	14	24
Algol 1	...	2.7v	1	2	18	39	+22	25	41	3	07	50.5	+40	56	12
Alcyone 2	*Kṛttikā*	2.96	1	6	08	07	+4	03	02	3	47	11.2	+24	05	24
Aldebaran 3	*Rohiṇī*	1.06	1	15	55	56	-5	28	04	4	35	38.0	+16	29	58
Rigel 4	...	0.34	1	22	58	21	-31	07	24	5	14	17.8	-8	12	26
Bellatrix 5	...	1.70	1	27	05	22	-16	49	00	5	24	51.8	+6	20	44
Capella 6	*Brahmahṛday*	0.21	1	28	00	03	+22	51	51	5	16	19.1	+45	59	36
β Tauri	*Agni*	1.78	1	28	43	05	+5	23	05	5	25	58.5	+28	36	13
ε Orionis	...	1.75	1	29	36	24	-24	30	25	5	35	57.5	-1	12	17
λ Orionis	*Mṛgaśiras*	3.66	1	29	50	59	-13	22	12	5	34	51.7	+9	55	52
Polaris	*Dhruva*	2.1v	2	4	42	39	+66	06	03	2	26	21.9	+89	14	31

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	
Betelguese 7	*Ārdrā*	0.6v	2	4	53	51	-16	01	40	5	54	54.1	+7	24	23
Sirius 8	*Lubdhaka*	-1.58	2	20	13	32	-39	36	15	6	44	55.6	-16	42	32
Canopus 9	*Agastya*	-0.86	2	21	06	17	-75	49	28	6	23	50.6	-52	41	34
Castor 10	...	1.99	2	26	23	02	+10	05	44	7	34	16.9	+31	53	59
Pollux 11	*Punarvasu*	1.21	2	29	21	34	+6	41	02	7	45	00.6	+28	02	19
Procyon 12	...	0.48	3	1	55	46	-16	01	07	7	39	01.7	+5	14	17
δ Cancri	*Puṣya*	4.17	3	14	51	54	+0	04	37	8	44	24.1	+18	10	23
ε Hydrae	*Āśleṣā*	3.48	3	18	29	18	-11	06	15	8	46	30.7	+6	26	14
α Cancri	”	4.27	3	19	47	05	-5	04	51	8	58	12.8	+11	52	38
Dubhe 13	*Kratu*	1.95	3	21	20	25	+49	40	47	11	03	25.3	+61	46	41
Regulus 14	*Makhā*	1.34	4	5	58	21	+0	27	53	10	08	06.3	+11	59	30
δ Leonis	*Pūrva Phālgunī*	2.58	4	17	27	33	+14	20	00	11	13	50.6	+20	33	04
Denebola 15	*Uttara Phālgunī*	2.23	4	27	45	39	+12	16	02	11	48	48.3	+14	36	00
δ Corvi	*Hasta*	3.11	5	19	35	42	-12	11	45	12	29	36.3	-16	29	16
Spica 16	*Citrā*	1.21	5	29	59	03	-2	03	15	13	24	35.7	-11	08	07

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
Arcturus 17	*Svātī*	0.24	6	0	22	36	+30	44	23	14	15	26.0	+19	12	30
α Libra	*Viśākhā*	2.90	6	21	13	32	+0	20	01	14	50	36.1	-16	01	16
β Centauri	...	0.86	6	29	56	09	-44	08	13	14	03	28.0	-60	20	57
α Centauri	...	0.06	7	5	37	45	-42	35	39	14	39	15.3	-60	48	54
δ Scorpii	*Anurādhā*	2.54	7	8	42	50	-1	59	08	16	00	02.2	-22	36	28
Antares 18	*Jyeṣṭhā*	1.2v	7	15	54	19	-4	34	09	16	29	06.0	-26	25	16
λ Scorpii	*Mūlā*	1.71	8	0	43	43	-13	47	16	17	33	16.1	-37	06	02
δ Sagittarii	*Pūrvāsāḍhā*	2.84	8	10	43	26	-6	28	18	18	20	40.5	-29	49	52
ε Sagittarii	...	1.95	8	11	13	18	-11	03	04	18	23	50.4	-34	23	14
δ Sagittarii	*Uttarāṣāḍhā*	2.14	8	18	31	41	-3	26	56	18	54	57.3	-26	18	12
Vega 19	*Abhijit*	0.14	8	21	27	31	+61	43	59	18	36	46.1	+38	46	44
Altair 20	*Śravaṇa*	0.89	9	7	55	06	+29	18	13	19	50	32.4	+8	51	18
β Capricorni	...	3.25	9	10	11	25	+4	35	21	20	20	43.8	-14	47	51
β Delphini	*Dhaniṣṭhā*	3.72	9	22	29	04	+31	55	07	20	37	18.9	+14	34	39
α Delphini	...	3.86	9	23	31	25	+33	01	22	20	39	24.4	+15	53	39
Formalhaut 21	...	1.29	10	10	00	10	-21	08	06	22	57	22.5	-29	38	36

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
Deneb 22	...	1.33	10	11	28	23	+59	54	24	20	41	15.7	+45	15	44
λ Aquarii	*Śatabhiṣaj*	3.84	10	17	43	08	-0	23	11	22	52	21.2	-7	36	23
Achernar 23	...	0.60	10	21	27	12	-59	22	41	1	37	31.7	-57	15	43
Markab 24	*Pūrvābhādrapada*	2.57	10	29	37	43	+19	24	22	23	04	30.7	+15	10	42
β Pegasi	...	2.6v	11	5	31	02	+31	08	26	23	03	31.9	+28	03	20
γ Pegasi	*Uttarābhādhrapada*	2.87	11	15	17	57	+12	36	00	0	12	58.7	+15	09	21
α Andromeda	...	2.15	11	20	27	06	+25	40	50	0	08	07.7	+29	03	45
ζ Piscium	*Revatī*	5.57	11	26	01	13	-0	12	48	1	13	28.2	+7	32	56

1. β Persei	7. α Orionis	13. α Ursae Majoris	19. α Lyrae
2. η Tauri	8. α Canis Majoris	14. α Leonis	20. α Aquilae
3. α Tauri	9. α Carinae	15. β Leonis	21. α Piscis Austrini
4. β Orionis	10. β Germinorum	16. α Virginis	22. α Cygni
5. γ Orionis	11. α Germinorum	17. α Bootis	23. α Eridani
6. α Aurigae	12. α Canis Minoris	18. α Scorpii	24. α Pegasi

Table 11.4 Distribution of *Nakṣatra Pādas* into *Rāśis*

No.	*Nirayaṇa Rāśi*	*Nakṣatra*	*Pādas* included
1.	*Meṣa*	*Aśvini*	All
		Bharaṇī	All
		Kṛttikā	1
2.	*Vṛṣabha*	*Kṛttikā*	2, 3, 4
		Rohiṇī	All
		Mṛgaśira	1, 2
3.	*Mithuna*	*Mṛgaśira*	3, 4
		Ārdrā	All
		Punarvasu	1, 2, 3
4.	*Karkaṭaka*	*Punarvasu*	4
		Puṣya	All
		Āśleṣā	All
5.	*Simha*	*Makhā*	All
		*Pubba**	All
		*Uttarā***	1
6.	*Kanyā*	*Uttarā***	2, 3, 4
		Hasta	All
		Cittā (Citrā)	1, 2
7.	*Tulā*	*Cittā (Citrā)*	3, 4
		Svātī	All
		Viśākhā	1, 2, 3
8.	*Vṛścika*	*Viśākhā*	4
		Anurādhā	All
		Jyeṣṭhā	All
9.	*Dhanus*	*Mūlā*	All
		Pūrvāṣāḍhā	All
		Uttarāṣāḍhā	1
10.	*Makara*	*Uttarāṣāḍhā*	2, 3, 4
		Śravaṇa	All
		Dhaniṣṭhā	1, 2
11.	*Kumbha*	*Dhaniṣṭhā*	3, 4
		Śatabhiṣaj	All
		Pūrvābhādrā	1, 2, 3
12.	*Mīna*	*Pūrvābhādrā*	4
		Uttarābhādrā	All
		Revatī	All

* *Pūrva Phālguṇī* is referred to as *Pubba*.

** *Uttara Phālguṇī* is referred to as *Uttarā*.

Example : We shall find the *dhruva* of *Aśvinī* for *Kāśī* whose *palabhā* is $5|45$ *angulas*. The *śara* of *Aśvinī* is 10° (given in *Śloka* 3) and its *dhruva* is 8°. Multiplying the *śara* by *palabhā* we get $10 \times (5|45) = 57|30$. Dividing this by 12, we get $4^\circ\ 47'\ 30''$. Since *śara* is north, the result is subtracted from the *dhruva* of *Aśvinī* (eastern) to get the *udaya* (rising) *dhruva* of *Aśvinī* at *Kāśī*

i.e., *Udaya dhruva* of *Aśvinī* $= 8^\circ - 4^\circ\ 47'\ 30'' = 3^\circ\ 12'\ 30''$.

Similarly, performing the reverse operation we get the *asta* (setting) *dhruva* of *Aśvinī* viz., $8^\circ + 4^\circ\ 47'\ 30'' = 12^\circ\ 47'\ 30''$.

***Śloka* 6** : By considering the *dhruva* of a *nakṣatra* for the given place, similar to that of a planet, find the *cara* (from the *dhruva*) and hence the *dinamānam, unnata, nata, karṇa* and hence *yantrabhāga* (discussed in *tripraśnādhikāra*). The *chāyā, rātrigata kāla* (time elapsed during night) and the *yantrabhāga* are determined as in the case of a planet (discussed in the chapter *Grahacchāya*). Further, the conjunction of a star and a planet can be worked out as in the case of *grahayuti* (conjunction of planets).

Remark : Though Gaṇeśa Daivajña has not explained, in clear terms, the obtaining of conjunction of a planet and a star (*graha nakṣatra yuti*), his nephew (brother's son) Nṛsimha Daivajña has discussed the same in detail in his handbook.

Śloka* 7** : ***Rohiṇī śakaṭa bheda (breaking of *Rohiṇī* cart) is explained. If a planet is at 17° of *Vṛṣabha*, having its *śara* southern and greater than 50 *aṅgulas*, it is said to "break the *Rohiṇī* cart (wain)." (It is believed that) if any one of Kuja, Śani and Candra breaks the *Rohiṇī* cart then there will be a great calamity.

Śloka 8 : Determination of the *Rohiṇī sakaṭa bheda* of the Moon is explained.

As long as Rāhu is in the eight *nakṣatras* from *Punarvasu* to *Citrā* the Moon breaks the *Rohiṇī* cart.

In fact, for this configuration, actually, Rāhu must lie between about $80^\circ.75$ and $193^\circ.25$ i.e., just after the beginning of *Punarvasu* and before the end of the second *pāda* of *Svātī*.

Explanation : The *Rohiṇī* asterism is composed of five important stars (with southern latitudes) in the constellation of *Vṛṣabha* and is said to be in the shape of a cart (*śakaṭa*). The celestial longitudes vary from $45^\circ\ 46'$ to $49^\circ\ 45'$ i.e., around 17° of Taurus. The latitudes of these stars vary from $2^\circ\ 36'$ to $5^\circ\ 47'$ i.e., from $156'$ to $347'$ or 52 *aṅgulas* to about 116 *aṅgulas*. Therefore, to enter the 'cart' (wain) of *Rohiṇī* a planet must have more than 2.5° latitude (i.e., 50 *aṅgulas*). Thus, Gaṇeśa Daivajña prescribed 50 *aṅgulas* (negative) of *śara* for the *Rohiṇī śakaṭa bheda*.

Considering the well-known expression for the latitude (*śara*) of the Moon, we have

$$\beta = 270' \sin (R - M)$$

where β is the south latitude of the Moon (in minutes, *kalās*), R and M are respectively the longitudes of Rāhu and the Moon. Now, *GL* prescribes β to be above 50 *aṅgulas* i.e., $150'$ for the *Rohiṇī śakaṭa bheda*.

$$\therefore \quad 270' \sin (R - M) > 150'$$

$$\text{i.e.,} \quad \sin (R - M) > \frac{150'}{270'} = \frac{5}{9}$$

i.e., $$(R - M) > \begin{cases} \sin^{-1}\dfrac{5}{9} \approx 33^\circ.4 \\ 180^\circ - \sin^{-1}\dfrac{5}{9} \approx 146^\circ.6 \end{cases}$$

or $$R > \begin{cases} 33^\circ.4 + 47^\circ = 80^\circ.4 \\ 146^\circ.6 + 47^\circ = 193^\circ.6 \end{cases}$$

i.e., Rāhu should lie between $80^\circ.4$ and $193^\circ.6$

***Śloka* 9** : Finding the *lagna* and the time by observing a star on the meridian in the night is explained.

By the *dhruva* of a star on the meridian of a place in the night, its *cara* is determined. From this the half-day duration (*dinārdha*) is found out. Treating the star as the Sun, and adding *ayanāṁśa* to its *dhruva*, the *udaya lagna* for that instant at the given place is determined using the rising durations of the *rāśis* at the place. Now, adding six *rāśis* to the position of the Sun and taking the difference between that *rāśi* and the one of the current *lagna* (from the star on the meridian), the total rising durations of these *rāśis* give the time at the instant from the sunset.

Example : *Aśvinī dhruva* = $0^R\ 8^\circ$, *Ayanāṁśa* = $18^\circ\ 10'$. Therefore *sāyana Aśvinī dhruva* = $0^R\ 26^\circ\ 10'$. From this, the *cara* = $+\,49^{vig}$. Therefore *dinārdham* (half-day duration) is $15^{gh}\ 49^{vig}$. The *bhogya kāla is* 28^{vig}. Since *iṣṭakāla* = $15^{gh}\ 49^{vig}$, by the method explained earlier, the *madhya lagna* is $3^R\ 13^\circ\ 44'\ 46''$.

***Śloka* 10** : The *udaya dhruva* of the *nakṣatra* at the rising (eastern) horizon for the given place is the first *lagna* of the given time (*iṣṭakāla*) and

the *asta dhruva* of the *nakṣatra* at the setting (western) horizon, for the given place to which six *raśis* is added becomes the *asta lagna*. To the position of the Sun 6 *rāśis* when added and from the *asta lagna* of the *nakṣatra*, we can find the time elapsed since sunset at the place.

Example : *Aśvinī nakṣatra udaya dhruva* is $0^R\ 3°\ 12'\ 30''$ (obtained in the example under *Śloka* 3). This itself is the *udaya lagna*. The *asta dhruva* of *Aśvinī nakṣatra* is $0^R\ 12°\ 47'\ 30''$. Adding 6 *rāśis* to this we get $6^R\ 12°\ 47'\ 30''$. In this manner the *udaya* and *asta lagnas* of all bodies can be obtained.

***Śloka* 11** : In this manner, for a given place the rising (*udaya*), the meridian (*khamadhya*) and setting (*asta*) *sthira* (fixed) *lagnas* of *nakṣatras* can be determined.

Note : In Viśvanātha's commentary the *asta dhruvaka* of *Aśvinī* is given as $6^R\ 3°\ 47'\ 30''$.

CHAPTER 12
ŚṚṄGONNATYADHIKĀRAḤ
(Elevation of the Moon's Cusps)

In this chapter the discussion is on the determination of the time of the Moon's disappearance in the neighbourhood of the Sun or its re-appearance.

Ślokas 1 : This śloka tells how to find the gata and gamya tithi at the sunrise and at the sunset on a given day on which sṛṅgonnati is to be determined.

In the course of a lunar month, in its first quarter (i.e., from pratipat to 7.5 tithi of the bright half) or in the last quarter (i.e., from 7.5 tithi to the amāvāsyā), on the day when the Moon's sṛṅgonnati (elevation of the Moon's horns) is to be observed, the gata (elapsed) and the gamya (to be covered) parts of the tithi (with day, gh. and vig.) have to be known respectively at the sunset and the sunrise.

Example : The given date is May 27, 1610 (G).

Śaka = 1532 Jyeṣṭa Śukla 5 (Pañcamī), Thursday.

Cakra = 8, Ahargaṇa = 803

Mean Sun = $1^R\ 16^\circ\ 33'\ 54''$, Mean Moon = $3^R\ 9^\circ\ 33'\ 9''$

Candrocca = $7^R\ 24^\circ\ 57'\ 48''$, Rāhu = $2^R\ 22^\circ\ 24'\ 23''$

Mandakendra of Ravi = $1^R\ 1^\circ\ 26'\ 06''$

Mandaphala of Ravi = $+1^\circ\ 8'\ 22''$

Manda corrected Ravi = $1^R\ 17^\circ\ 42'\ 16''$, Ayanāṃśa = $18^\circ\ 08'$

Cara = $-106''$

True (Spaṣta) Ravi = $1^R\ 17^\circ\ 40'\ 30''$,

True motion of Ravi = $56'\ 20''$

Mandakendra of the Moon = $4^R\ 15^\circ\ 24'\ 39''$

Phala traya samskṛta Candra = $3^R\ 09^\circ 01'\ 28''$

Mandaphala of the Moon = $+\ 3^\circ\ 29'\ 21''$

$\therefore$ True Moon = $3^R\ 12^\circ\ 30'\ 49''$

True daily motion of the Moon = $837'\ 13''$

and dinamānam = $33^{gh}\ 32^{vig}$.

Ślokas 2 and 3 : These two ślokas explain the method of finding valanam. To find this we shall obtain the gata and gamya tithi at the time of sunrise or sunset.

(1) If the given day is in the first caraṇa (quarter) of the māsa (lunar month) i.e., from the pratipat (first day) to aṣṭamī of the śukla pakṣa, find tithi at the sunset. If the given day is in the final (antima) caraṇa i.e., from Aṣṭamī to amāvāsyā of the kṛṣṇa pakṣa, find the tithi at the sunrise.

(2) Find the sāvayava tithi (i.e., past tithi plus fraction of the current tithi) as above and multilply it by 12. The product gives antarāṃśa of the Sun and the Moon.

(3) The bove antarāṃśa is added to or subtracted from the true Sun, to get the true Moon at that instant. If the given date is in the prathama caraṇa then the antarāmśa is additive. If the date is in the antima caraṇa, then the product (antarāmśa) in (2) is subtractive.

(4) Multiply the tithi by 16.

(5) Square the tithi.

(6) Consider result of (4) – result of (5).

(7) Multiply the above difference by the palabhā of the place and divide by 15.

(8) Add the above result to the declination of the Sun.

(9) Find the Moon's śara from (Moon – Rāhu) in aṅgulas. Convert it into kalās by multiplying it by 3.

(10) Find the declination of the Moon. Subtract this from the difference of result (8) and (9). This is the required numerator to find the valanam.

(11) Multiply the tithi by 2. This is the denominator to find the valanam.

(12) Valanam = $\frac{\text{result of (10)}}{\text{result of (11)}}$ aṅgulas

(13) Sitam (or Śuklamāna) = $\left(\text{tithi} - \frac{\text{tithi}}{5}\right)$ aṅgulas

Example : (1) The given gata tithi is pañcamī in the prathama caraṇa. Therefore we shall find sāvayava tithi at the sunset.

At this instant, we have

True Sun = $1^R\ 18^\circ\ 12'\ 32''$, True Moon = $3^R\ 19^\circ\ 48'\ 2''$

and Rāhu = $2^R\ 22^\circ\ 22'\ 38''$

(2) Sāvayava tithi = $5^{d}\ 7^{gh}\ 20^{vig}\ 02^{pvg}$. Multiplying this by 12, we get the difference between the Sun and the Moon called antarāṃśa.

i.e., antarāṃśa (difference) = $(5|7|20|2)\times 12 = 61^\circ\ 28'\ 0''$

(3) The Sun at the sunset = $1^{R}\ 18^\circ\ 12'\ 32''$.

Adding antarāṃśa to the Sun, we get the position of the true Moon at the sunset

i.e., Moon at sunset = Sun at sunset + antarāṃśa

$$= 1^{R}\ 18^\circ\ 12'\ 32'' + 61^\circ\ 28'\ 0'' = 3^{R}\ 19^\circ\ 40'\ 32''$$

(4) Multiplying the sāvayava tithi by 16, we get $(5|7|20|2)\times 16 = 81|57|20$.

(5) Squaring the sāvayava tithi, $(5|7|20|2)^2 = 26|14|13$.

(6) Difference of the above two [i.e., (4) – (5)]

$= 81|57|20 - 26|14|13 = 55|43|7$

(7) Palabhā = $5|45$ aṅgulas

Now, $\dfrac{(55|43|7)\times(5|45)}{15} = \dfrac{320|22|55}{15} = 21|21|31$ (north).

(8) Declination of the Sun = $21^\circ\ 44'\ 29''$ (north)

The sum of the results of (7) and (8) is

$21^\circ\ 44'\ 29'' + 21^\circ\ 21'\ 31'' = 43^\circ\ 06'\ 0''$ (north)

(9) Moon – Rāhu = $27^\circ\ 25'\ 24''$

Moon's śara = $41|33|35$ aṅgulas (north) = $2^\circ\ 4'\ 10''$ in kalās (north)

(by multiplying by 3).

(10) Declination of the Moon = $18^\circ\ 36'\ 59''$ (north)

[**Note :** Using the trigonometric formula for declination δ viz., $\sin\delta = \sin\lambda \sin\varepsilon$ where $\varepsilon = 24^\circ$ and the Moon's sāyana longitude $\lambda = 109^\circ\ 40'\ 32'' + 18^\circ\ 08'$ = $127^\circ\ 48'\ 32''$, we get $\delta = 18^\circ\ 44'$].

From steps (8) and (9), we get

$43^\circ\ 6'\ 0'' - 2^\circ\ 4'\ 10''$ = $41^\circ\ 1'\ 50''$

$\therefore$ Numerator = $41^\circ\ 1'\ 50'' - 18^\circ\ 36'\ 59''$ = $22|24|51$ (north)

(for finding the valanam)

(11) Multiplying the sāvayava tithi by 2, we get

Denominator = $5|7|20 \times 2$ = $10|14|40$.

(for finding the valanam)

(12) Dividing the result of step (10) by that of (11), we have

$$\text{Valanam} = \frac{22|24|51}{10|14|40} = 2|11|6 \text{ aṅgulas (north)}$$

(13) Sitam (śukla māna) = $5|7|20 - \dfrac{5|7|20}{5}$ = $4|5|52$ aṅgulas

Śloka 4 : This śloka explains the direction of śṛṅgonnati and natam.

(1) The direction of śṛṅgonnati of the Moon is in the direction of the valanam.

(2) The nata will be in the opposite direction of the valanam.

In this case there is no need for parilekhā.

CHAPTER 13

GRAHAYUTYADHIKĀRAḤ

(Conjunction of Planets)

In this chapter, the method of determining the instant of conjunciton (grahayuti or grahayoga) of two planets is discussed by considering their true angular diameters.

Śloka 1 : This śloka explains the method of finding (true) diameters of planets whose yuti (conjunction) is to be found out. It is as follows :

(1) The mean diameters (in kalās) of planets are given in Table 13.1.

Table 13.1 Planets' diameters

Planets	Mean diameters in kalās
Kuja	5
Budha	6
Guru	7
Śukra	9
Śani	5

(2) Find the śīghrakarṇa of the planet of which diameter is required.

(3) Subtract śīghrakarṇa from 11. Multiply this result by its mean diameter.

(4) Divide the product by 21, 12, 6, 24 and 3 for Kuja, Budha, Guru, Śukra and Śani respectively.

(5) If the śīghrakarṇa of the planet is greater than 11, subtract the above quotient from the mean diameter. If the śīghrakarṇa is less than 11, then add the above quotient to the mean diameter (in kalās).

(6) The result of step (5) divided by 3 gives the diameter of the planet in aṅgulas.

i.e.,

$$\left.\begin{array}{l}\text{Diameter}\\\text{of the planet}\end{array}\right\}=\frac{\left[\text{Mean diameter}\pm\frac{(11-\text{śighrakarṇa})}{n}\times\text{Mean diameter}\right]}{3}$$

where n = 21, 12, 6, 24 and 3 for Kuja, Budha, Guru, Śukra and Śani respectively.

Example : Given date is May 2, 1610 (G), Sunday

i.e., Samvat year 1667, Śaka year 1532

Vaiśākha śukla 10 (daśamī)

Cakra = 8, Ahargaṇa = 778

For the given date, we have

Mean Ravi = $0^R\ 21^\circ\ 55'\ 30''$ True Ravi = $0^R\ 23^\circ\ 42'\ 41''$

Mean Kuja = $9^R\ 0^\circ\ 33'\ 51''$ True Kuja = $10^R\ 6^\circ\ 35'\ 9''$

Mean Śani = $10^R\ 5^\circ\ 45'\ 59''$ True Śani = $10^R\ 2^\circ\ 58'\ 44''$

True daily motion of Ravi = $57'\ 56''$

True daily motion of Kuja = $42'\ 50''$

True daily motion of Śani = $3'\ 3''$

Ayanāṃśa = $18^\circ\ 08'$ Cara = $-75''$ Dinamānam = $31^{gh}\ 30^{vig}$

(1) Śīghrakarṇa of Kuja = $8|52$ śīghrakarṇa of Śani = $11|13$

Mean diameter of Kuja = 5 kalās Mean diameter of Śani = 5 kalās

n = 21 for Kuja and n = 3 for Śani

$$\therefore \quad \left.\begin{array}{l}\text{Diameter of}\\ \text{Kuja}\end{array}\right\} = \frac{1}{3}\left[5 + \frac{(11 - 8|52)}{5} \times 5\right] \text{ aṅgulas} = 1|50 \text{ aṅg.}$$

$$\left.\begin{array}{l}\text{Diameter of}\\ \text{Śani}\end{array}\right\} = \frac{1}{3}\left[5 + \frac{(11 - 11|13)}{3} \times 5\right] \text{ aṅgulas} = 1|33 \text{ aṅg.}$$

Śloka 2 : This śloka explains about the gata and gamya (eṣya) of grahayuti on a given day. i.e., whether the conjunction (yuti) is over (gata) or yet to take place (gamya).

(1) Of the planets of which yuti is to be determined, if the longitude of the planet having greater motion is greater than that of the planet having lesser motion, then this implies that the yuti is over.

(2) If the longitude of the planet having retrograde motion is less than that of the planet having direct motion then yuti is over.

(3) If both planets are in retrograde motion and the longitude of the planet having greater motion (fast moving) is less than that of the planet having lower motion (slow moving) then we have to understand that the yuti is over.

(4) If the conditions of the two planets are different from the above conditions, then their conjunction is yet to take place.

Example : For the given day, at the mean sunrise, we have

True Śani = $10^R\ 2^\circ\ 58'\ 44''$, True Kuja = $10^R\ 6^\circ\ 35'\ 9''$

True daily motion of Śani = $3' 3''$, True daily motion of Kuja = $42' 50''$.

We note that Kuja is the faster moving planet than Śani and has greater longitude. Therfore, their yuti is over. Here both Kuja and Śani are in direct motion.

Śloka 3 : This śloka tells about the number of days by which the yuti is over if it is over and the number of days for the yuti to occur if it is yet to occur.

(1) If both the planets are either in direct motion or in retrograde motion then divide the difference between their positions expressed in kalās by the difference between their daily motions in kalās. The result will be in days, ghaṭīs etc. which gives the number of days by which the yuti is over or the number of days for the yuti to occur as the case may be.

(2) Of the two planets if one is in direct motion and the other is in retrograde motion, then divide the difference between their positions by the sum of their daily motions. This result gives the number of days by which the yuti is over or the number of days for the yuti to occur.

Example : We have Kuja, $P_1 = 10^R\ 6^\circ\ 35'\ 9''$; Śani, $P_2 = 10^R\ 2^\circ\ 58'\ 44''$.

Kuja and Śani both are in direct motion.

Then the number of days for yuti = $\dfrac{P_1 - P_2}{DP_1 - DP_2}$

where we have the difference in the longitudes of Kuja and Śani,

$$P_1 - P_2 \equiv 3^\circ\ 36'\ 25'' = 216'\ 25''.$$

Difference between their daily motions

$$DP_1 - DP_2 = 42'\ 50'' - 3'\ 3'' = 39'\ 47''$$

$\therefore$ Days for the yuti = $\dfrac{216'\ 25''}{39'\ 47''} = 5^d\ 26^{gh}\ 23^{vig}$

Since the longitude of Kuja > Śani, the yuti is over by $5^{d}\ 26^{gh}\ 23^{vig}$ for the given date.

Given date is the Daśamī of Vaiśākha Śukla and therefore the yuti was on Caturthī of Vaiśākha Śukla elapsed ghatīs at the sunrise = $33^{gh}\ 37^{vig}$.

Ratri gata ghaṭīs = $2|7$ gh. (since the dinamāna on that Caturthī day is $31|30$ gh.).

Śloka 4: The day and time of the conjunction of two planets is first obtained and their longitudes, which are the same, are found out. If the Moon's conjuction with a planet is required then, as in the case of the solar eclipse the śara (latitude) of the Moon is corrected for its nati. Find the śaras of the two bodies. A planet is in the same direction (north or south) as its śara. If their śaras are in the same direction, then that with the less śara (numerically) is considered as of opposite direction from that with (numerically) greater śara. If the śaras are in the same direction, take their difference and if they are of opposite directions, consider their numerical sum. Find the mānaikyakhaṇḍa (i.e., the sum of the semi-diameters of the planets). If the mānaikyakhaṇḍa is less than the difference of śaras, then there is no bhedayoga and hence no need of lambana etc.

If the difference of śaras is less than the mānaikyakhaṇḍa then there is bhedayoga. In that case, considering the lower body (relatively southern) as the Moon and the upper body as the Sun - as for a solar eclipse - find the lagna, lambana etc. From this the corrected sparśa kāla etc. is determined.

Example : In the example considered under Śloka 3, from the given daśamī day, $5^{d}\ 26^{gh}\ 23^{vig}$ earlier the yuti of Kuja and Śani took place. For this date (of conjuction), the (negative) motions of Kuja and Śani are

$3^\circ 53' 0$ and $0^\circ 16' 35''$ so that true Kuja = $10^R\ 2^\circ\ 42'\ 09''$ and true Śani = $10^R\ 2^\circ\ 42'\ 09''$. The manda spaṣṭa cālanam (motion) of Kuja is $3^\circ\ 22'\ 32''$ and that for Śani is $0^\circ\ 10'\ 03''$. Therefore, manda spaṣṭa Kuja = $8^R\ 25^\circ\ 08'\ 27''$ and manda spaṣṭa Śani = $9^R\ 27^\circ\ 13' 15''$. Kuja's Pāta = $1^R\ 10^\circ$. Kuja – Pāta = $7^R\ 15^\circ\ 08'\ 27''$. The krānti of the above result is $16^\circ\ 38'\ 32''$ (south). Multiplying this by 23 we get $382|46|16$. Dividing this by śīghrakarṇa $8|52$, we get $43|10$. Subtracting $\frac{1}{4}$th of this we get $43|10 - \frac{1}{4}(43|10) = 32|23$. Dividing this by 2, we get Kuja's śara (latitude) = $16|11$ aṅgulas. The śara is south since (Kuja – Pāta) is south (since it is greater than 180°). Similarly, Śani's śara = $14|07$ aṅg. (south). Since the śaras of the both the planets are in the same direction (south), the one with the less śara i.e., Śani is in the opposite direction (i.e., north) with respect to Kuja. Since they are in the same direction

the difference of śaras = $16|11 - 14|07 = 2|4$ aṅg.

Mānaikya khaṇḍa = $\frac{1}{2}$ (Śani *bimba* + Kuja *bimba*) = $\frac{1}{2}(1|50 + 1|33)$ = $1|41$ aṅg.

Since the mānaikya khaṇḍa is less than the difference of śaras $(1|41 < 2|4)$, there will be no bheda yoga. Therefore, lambana etc. need not be found.

On the other hand, if there is bheda yoga then the planet which is lower is treated as the Moon and the higher one as the Sun. Then lambana, nati etc. are worked out as in the case of the solar eclipse.

CHAPTER 14

PĀTĀDHIKĀRAḤ

(Parallel Aspects of Sun and Moon)

The equality of the declinations of the Sun and the Moon, in magnitude (with the same or opposite signs), is called vyatīpāta or vaidhṛtipāta according as the declinations of the Sun and the Moon are on the same side or on the opposite sides of the celestial equator. In Western astrology these are referred to as "parallel" aspects of the Sun and the Moon.

Śloka 1 : The method of finding vyatīpāta and vaidhṛti pāta is explained as follows.

(1) Multiply ayanāmśa by 9. Divide the product by 60 to get the result in ghaṭīs.

(2) Subtract the result of step (1) from 13|30. The difference is called sāvayava yoga. If this yoga is elapsed (gata) yoga then there will be vyatīpāta.

(3) Subtract the result of step (1) from 27. The difference is called sāvayava yoga. If this is gata yoga, then there will be vaidhṛti pāta.

(4) Correction to be applied to yoga ghaṭīs to get corrected ghaṭīs :

Multiply gatayoga ghaṭīs by the sum of gata (elapsed) and eṣya (remaining) ghaṭīs of the nakṣatra at that instant. Divide the product by 65. The result gives corrected gata yoga ghaṭīs.

Note : While calculating a pāta, sāyana Ravi and sāyana Rāhu are to be considered.

Example : Given date is Samvat year 1670, Śaka year 1535 Vaiśākha Kṛṣṇa Saptamī, Saturday i.e. May 11, 1613 (G)

Cakra = 8, Ahargaṇa = 1883

Given time = $11|35$ ghaṭīs (after the sunrise)

Dhaniṣṭhā nakṣatra ghaṭī = $59|3$ ghaṭīs

Brahmayoga ghaṭī = $27|46$ ghaṭīs

Mean Sun = $1^R\ 1^\circ\ 0'\ 9''$, Mean Moon = $9^R\ 20^\circ\ 0'\ 44''$

Candrocca = $11^R\ 25^\circ\ 13'\ 14''$, Rāhu = $0^R\ 25^\circ\ 9'\ 52''$

Ayanāmśa = $18^\circ\ 11'$, Cara = -88

True Sun = $1^R\ 2^\circ\ 35'\ 6''$, True Moon = $9^R\ 24^\circ\ 8'\ 35''$

True daily motion of the Sun = $57'\ 33''$

True daily motion of the Moon = $762'\ 49''$

gata (elapsed) part of Dhaniṣṭhā nakṣatra = $3^{gh}\ 49^{vig}$

eṣya (remaining) part of Dhaniṣṭhā = $59^{gh}\ 06^{vig}$

Sum of the gata and eṣya ghaṭīs = $3^{gh}\ 49^{vig} + 59^{gh}\ 06^{vig}$

i.e., total duration of the Dhaniṣṭhā nakṣatra = $62^{gh}\ 55^{vig}$

(1) $\dfrac{\text{ayanāṃśa} \times 9}{60} = \dfrac{18|11 \times 9}{60} = 2^{gh}\ 43^{vig}\ 39^{p.vig}$

(2) For the vyatīpāta yoga we have

sāvayava yoga ghaṭī = $13|30 - 2|43|39 = 10|46|21$

When the sāvayava yoga is completed then there will be vyatīpāta.

(3) Now, for the Vaidhṛtiyoga, we have

sāvayava yoga = $27 - 2|43|39 = 24|16|21$

If this is completed, then there will be Vaidhṛti pāta.

(4) Ghaṭī spaṣṭīkaraṇa (correction to get spaṣṭa ghaṭī) :

Given Brahma yoga gata ghaṭī = $16|21$ ghaṭīs

Sum of the gata (elapsed) and the eṣya (balance) ghaṭīs of

Dhaniṣṭhā nakṣatra = $62|55$ ghaṭīs

Now, $\dfrac{16|21 \times 62|55}{65} = 15|49$ ghaṭīs

i.e., corrected (spaṣṭa) ghaṭī = $15|49$ ghaṭīs.

On the previous day (Friday), Śukla yoga ghaṭī = $30|01$. Adding the spaṣṭa gata ghaṭī of the Brahma yoga $15|49$ (obtained above), we get $45|50$ gh. The balance ghaṭīs for the next sunrise is $60\text{ gh.} - 45|50\text{ gh.} = 14|10\text{ gh.}$ At that instant, we have

True Ravi = $1^R\ 2^\circ\ 21'\ 31''$, Rāhu = $0^R\ 25^\circ\ 10'\ 37''$

$\therefore$ Sāyana Ravi = $1^R\ 20^\circ\ 33'\ 31''$, Sāyana Rāhu = $1^R\ 13^\circ\ 21'\ 37''$

These are the positions at the mean time of equality of the declinations of the Sun and the Moon (madhyama krānti sāmya kāla).

Note : (i) The pātayoga occurs when the declinations of the Sun and the Moon, become equal.

(ii) When sāyana Ravi + sāyana Candra = 6 rāśis

there will be vyatī pāta (approximately).

When sāyana Ravi + sāyana Candra = 12 rāśis

there will be vaidhṛti pāta (approximately).

At the above instant the declinations of the Sun and the Moon will be nearly equal in magnitude and these two pātas occur in different months. For the actual instant of the two pātas, the declinations must be equal rather than the sum of the sāyana Sun and Moon being 6^R or 12^R.

Remark :

(i) Sāyana Ravi + sāyana Candra

= Ravi + Candra + 2 $\times$ ayanāṃśa

When the above sum is equal to 6 rāśis

i.e., Ravi + Candra + 2 $\times$ ayanāṃśa = 180°, we have

Ravi + Candra = $180^\circ - 2\times$ ayanāṃśa [in degrees]

= $180^\circ \times 60' - 60' \times 2$ ayanāṃśa [in kalās]

$$= 180^\circ \times 60' - 60' \times 60^{gh} \times 2 \text{ ayanāṃśa}$$

[where Ravi and Candra are the nirayaṇa Sun and Moon]

$$\therefore \text{ gata yoga saṇkhyā} = \frac{180^\circ \times 60'}{800} - \frac{60^{gh} \times 60' \times 2 \times \text{ayanāṃśa}}{800}$$

$$= \frac{108}{8} - 9^{gh} \times \text{ ayanāṃśa}$$

$$= 13|30 - 9 \text{ gh.} \times \text{ ayanāṃśa}$$

Similarly, when sāyana Ravi + sāyana Candra = $12^R = 360^\circ$,

we get yogasaṇkhyā = 27 and we consider $27 - 9$ gh. $\times$ ayanāṃśa

(ii) If δ, λ and $\in$ are respectively the declination, the (sāyana) longitude and the obliquity of the ecliptic, then

$$\sin\delta = \sin\lambda \sin\in$$

for a body on the ecliptic (i.e., latitude $\beta = 0$).

Let δ_S and δ_M be respectively the declinations of the Sun and the Moon.

$$\therefore \quad \sin\delta_S = \sin\lambda_S \sin\in \qquad (1)$$

$$\text{and} \quad \sin\delta_M = \sin\lambda_M \sin\in \qquad (2)$$

(i) Suppose $\lambda_S + \lambda_M = 180^\circ$ so that $\lambda_S = 180^\circ - \lambda_M$

From (1) we have

$$\sin\delta_S = \sin(180^\circ - \lambda_M)\sin\in = \sin\lambda_M \sin\in \text{ [From (2)]},$$

i.e., $\sin \delta_S = \sin \delta_M$

$\delta_S = \delta_M$: Vyatipāta yoga

assuming that the latitude (śara) of the Moon is negligible.

(ii) Suppose $\lambda_S + \lambda_M = 360^\circ$ so that $\delta_S = 360^\circ - \lambda_M$

From (1), we have

$$\sin \delta_S = \sin (360^\circ - \lambda_M) \sin \in$$

$$= -\sin \lambda_M \sin \in = -\sin \delta_M \quad \text{[From (2)]}$$

or $\delta_S = -\delta_M$: Vaidhṛti pāta yoga

again assuming that the latitude of the Moon is negligible.

Thus, in the case of vyatīpāta yoga the declinations of the Sun and the Moon are equal both in magnitude and sign (i.e., both northern or both southern) or equivalently the sum of the sāyana longitudes of the Sun and the Moon must be 180°.

Similarly, in the case of vaidhṛti yoga the declinations have the same magnitude but opposite signs. Equivalently, the sum of the sāyana longitudes of the Sun and the Moon must be 360°.

In the above explanation it is assumed that the latitude (śara) of the Moon is zero. i.e., the Moon is almost on the ecliptic. However, the actual declination (δ), in terms of the longitude (λ) and latitude (β) is given by

$$\sin \delta = \sin \beta \cos \in + \cos \beta \sin \in \sin \lambda$$

where $\in$ is the obliquity of the ecliptic with the celestial equator.

Therefore, when the sum of the longitudes ($\lambda_S + \lambda_M$) of the Sun and the Moon is either 180° or 360°, their actual declinations are not equal (in

magnitude) but somewhat close in their values. As a first approximation, the instant of $(\lambda_S + \lambda_M)$ being either 180° or 360° is determined. For that instant the declinations δ_S and δ_M of the Sun and the Moon are close but not equal. Then to make the two declinations equal the actual instants are determined by successive approximation.

Ślokas 2, 3 and 4 : These three ślokas explain the condition under which either pāta yoga occurs.

(1) If the sarāhusūrya (Sun + Rāhu) and the Sun are in the same hemisphere, then there will be a pāta.

(2) If the sarāhusūrya and the Sun are in different hemispheres and the bhujāmśa of the Sun is less than 55°, then a pāta will take place.

(3) If the bhujāmśa of Ravi is greater than 55° in the above case, then there is doubt in pāta taking place. This situation can be dealt with as follows.

If the sarāhusūrya and Ravi are in the same type of quadrants (both even or both odd), the corresponding seven khaṇḍas are given by 0, 0, 1, 2, 6, 18, 57 respectively. In this case the kṣepa is 6.

If the sarāhusūrya and Ravi are in different types of quadrants, the khaṇḍas are 3, 7, 11, 16, 20, 23 respectively and the kśepa is 10.

Divide the koṭi of the Sun (sūryakoṭi) by 5. The resulting quotient gives the number of elapsed khaṇḍas. Add all these elapsed khaṇḍas. Take the product of the eṣyakhaṇḍa (to be covered) and the remainder. Divide this product by 5 and add the result and the kṣepa to the sum of the elapsed khaṇḍas. The result is called sandhi.

i.e., Sandhi =

$$\text{Sum of the elapsed khaṇḍas} + \left[\frac{\text{eṣyakhaṇḍa} \times \text{remainder}}{5}\right] + \text{kṣepa}$$

If the bhujāṃśa of sarāhusūrya is less than the sandhi then there is possibility of a pāta taking place. Otherwise, there will be no pāta, and in this case the difference between the bhujāṃśa and the sandhi is equal to the difference between the declinations.

Example : Suppose Sāyana Ravi = $1^R\ 27^\circ$, Sāyana Rāhu = $6^R\ 15^\circ$

$\therefore$ Sarāhusūrya = $8^R\ 12^\circ$

Bhujāṃśa of Ravi = 57° which is greater than 55°.

Koṭi of the Sun = $90^\circ - 57^\circ = 33^\circ$. Dividing by 5, we get

$\frac{33}{5} = 6 + \frac{3}{5}$. Here, quotient = 6, remainder = 3.

Now, quotient = 6 implies that the number of gata khaṇḍas is 6.

Sum of the gata khaṇḍas = 0 + 0 + 1 + 2 + 6 + 18 = 27

We have remainder = 3, eṣyakhaṇḍa = 57

Here we note that the sarāhusūrya (3rd quadrant) and Ravi (1st quad.) are in different hemispheres and they are in the same type of quadrants (both odd).

Sandhi = Sum of the gata khaṇḍas + $\left[\frac{\text{eṣyakhaṇḍa} \times \text{remainder}}{5}\right] + \text{kṣepa}$

$$= 27 + \left(\frac{57 \times 3}{5}\right) + 6 = 67^\circ\ 12'$$

Now Sandhi = $67^\circ\ 12'$

Bhujāṃśa of sūrāhusūrya = $8^R\ 12^\circ - 180^\circ = 252^\circ - 180^\circ = 72^\circ$

Since the bhujāṃśa of sarhusūrya is greater than the sandhi, there will be no pāta taking place. In this case, we have

bhujāṃśa – sandhi = $72^\circ - 67^\circ\ 12' = 4^\circ\ 48'$ is equal to the difference between the declinations of the Sun and the Moon.

Śloka 5 : This śloka explains the gata and gamya lakṣaṇa of a pāta.

(1) If sāyana Ravi is in the even quadrant, and sāyana Ravi as well as sarāhusūrya are in the same hemisphere, then this implies that the pāta is completed.

(2) If sāyana Ravi is in the odd quadrant and sāyana Ravi as well as sarāhusūrya are in different hemispheres, then the pāta is completed.

(3) If sāyana Ravi is in the even quadrant, and sāyana Ravi and sarāhusūrya are in different hemispheres, then the pāta is yet to take place.

(4) If sāyana Ravi is in the odd quadrant, and sāyana Ravi and sarāhusūrya are in the same hemisphere, then pāta is yet to occur.

In the case where sāyana Ravi and sarāhusūrya are in different hemispheres, find the śara (as explained in the next śloka). If the bhujāmśa of the sāyana Ravi is less than one-fourth of the śara, then treating Ravi as if in the quadrant opposite to its actual quadrant (i.e., odd and even quadrants reversed), the gata-gamya process of the pāta (described earlier) is followed. In this case when the Sun is in an odd quadrant and both the Sun and (Sun + Rāhu) are in the same hemisphere, the vaidhṛti is gamya (yet to occur).

Example : (Sāyana) Ravi = $1^R\ 20^\circ\ 33'\ 31''$ and (sāyana) Rāhu = $1^R\ 13^\circ\ 21'\ 37''$ so that (Rāhu + Ravi) = $3^R\ 3^\circ\ 55'\ 08''$. Since Ravi is in the

odd quadrant and Ravi as well as (Rāhu + Ravi) are in the same hemisphere (northern since the longitudes < 180°), the pāta is yet to takes place.

Śloka 6 : This śloka explains the method of finding the śara of sarāhusūrya using khaṇḍas which in turn is used to find pāta.

(1) The 18 śara khaṇḍas used in finding śara are 4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 2, 2, 2, 2, 1, 1, 0, 0.

(2) Divide the bhujāṃśa of sarāhusūrya by 5. The quotient gives the number of gata khaṇḍas.

(3) Add all these gatakhaṇḍas.

(4) Multiply the remainder in step (2) by eṣyakhaṇḍa and divide the product by 5.

(5) Add the results of step (3) and step (4). This gives the śara of sarāhusūrya.

$$\text{Śara} = \text{Sum of the gata khaṇḍas} + \frac{\text{remainder} \times \text{eṣyakhaṇḍa}}{5}$$

Example : We have Sarāhusūrya = $3^R\ 3^\circ\ 55'\ 8'' \equiv 93^\circ\ 55'\ 8''$

Bhuja of this = $86^\circ\ 4'\ 52'' \equiv (180^\circ - 93^\circ\ 55'\ 8'')$

(1) Now, $\dfrac{86^\circ\ 4'\ 52''}{5} = 17 + \dfrac{1^\circ\ 4'\ 52''}{5}$

quotient = 17 and remainder = $1^\circ\ 4'\ 52''$

(2) Sum of the 17 gata khaṇḍas = 45, eṣyakhaṇḍa = 0

(3) $\therefore$ Śara = $45 + \dfrac{1^\circ\ 4'\ 52'' \times 0}{5} = 45$ aṅgulas

Dividing śara by 4, we get $11|15$. Since the bhujāṃśa of sāyana Ravi viz., $50^\circ\ 33'\ 31''$ is not less than $11|15$, the problem of different quadrants does not arise.

Śloka 7 : This śloka explains the method of finding spaṣṭaśara as follows.

(1) Dividing bhujāṃśa of Sun by 10, we get 0, 1, 2, 3, 4, 5, 6, 7, 8 respectively. For these numbers the corresponding hāra are given as 12, 12, 14, 18, 27, 36, 70, 102, 337.

(2) Divide sāra by hāra. Subtract the quotient from śara. The result is called spaṣṭa śara. It is also called as krāntisaṃskāra yogya śara i.e., the śara fit to be used for correcting the krānti.

Example : Sāyana Ravi = $1^R\ 20^\circ\ 33'\ 31''$, its bhujāṃśa = $50^\circ\ 33'\ 31''$

Now, $\dfrac{50^\circ\ 33'\ 31''}{10} = 5 + \dfrac{0^\circ\ 33'\ 31''}{10}$

i.e., quotient = 5, remainder = $0^\circ\ 33'\ 31''$

Corresponding hāra = 36, eṣyahāra = 70

Difference = $70 - 36 = 34$

Now, spaṣṭa hāra = $\dfrac{\text{remainder} \times \text{difference}}{10} + \text{hara}$

$$= \frac{0^\circ\ 33'\ 31'' \times 34}{10} + 36 = 37|50$$

Śara = 45 aṅgulas (obtained in the previous śloka)

$$\text{Spaṣṭa śara} = \text{śara} - \frac{\text{śara}}{\text{hāra}} = 45|0 - \frac{45|0}{37|50} = 43|49 \text{ aṅgulas}$$

Śloka 8 : This śloka gives the 18 krānti aṅkas. They are 20, 20, 20, 20, 19, 18, 18, 16, 16, 14, 13, 12, 10, 8, 7, 5, 3, 1.

Divide the bhujāmśa of the Sun by 5. The quotient gives the corresponding krānti aṅka. Use the remainder as given in the following śloka.

Ślokas 9 and 10 : Here, the positions of krānti khaṇḍas and śara khaṇḍas and their samskāras (corrections) are explained. The earlier obtained aṅkas (values) of śara (latitude) and krānti (declination) are arranged in the given and opposite orders as follows :

Krānti aṇkas : 20, 20, 20, 20, 19, 18, 18, 16, 16, 14, 13, 12, 10, 8, 7, 5, 3, 1 in the given order.

Now, in the opposite order, these numbers are 1, 3, 5, 7, 8, 10, 12, 13, 14, 16, 16, 18, 18, 19, 20, 20, 20, 20.

Similarly, the śarāṅkas in the given and opposite orders are

4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 2, 2, 2, 2, 1, 1, 0, 0 and 0, 0, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4.

When the Sun is in the even quadrant, the krāntyaṅkas and when the sarāhu sūrya (i.e., Sun + Rāhu) is in the even quadrant the śarāṅkas must be considered.

Example : Sāyana Ravi : $0^R\ 25^\circ\ 52'\ 49''$ and sarāhu sūrya (Sūrya + Rāhu) : $4^R\ 28^\circ\ 58'\ 59''$. Since the sāyana Ravi is in the odd quadrant (1st) and both (sāyana) Ravi and sarāhusūrya are in the same hemisphere ($< 180^\circ$) the pāta is yet to take place (gamya pāta). Dividing the bhuja of the Sun i.e., $25^\circ\ 52'\ 49''$ by 5, we get the quotient as 5 and the remainder

$0^\circ\ 52'\ 49''$. Therefore, leaving the first 5 aṅkas (i.e., 20, 20, 20, 20, 19) among the listed krānti aṅkas, the next one is 18. The continuous six aṅkas from this number are 18, 18, 16, 16, 14 and 13. Similarly, sarāhu sūrya is $4^R\ 28^\circ\ 58'\ 59''$ in the even quadrant and the pāta is gamya. Dividing the bhuja of $4^R\ 28^\circ\ 58'\ 59''$ i.e., $1^R\ 1^\circ\ 01'\ 01''$ i.e., $31^\circ\ 1'\ 1''$ by 5, we get 6 khaṇḍas completed.

Ślokas 11 and 12 : Now, obtaining of the middle of pāta is expalined.

(i) Divide the remainder obtained in Śloka 7 by 5. Multiply the quotient by the first sphuṭāṅka (of the six aṅkas obtained for the sāyana Ravi from Ślokas 9 and 10). The product is called laghu.

(ii) Add spaṣṭa śara to this product (laghu).

(iii) Subtract the previously obtained six aṅkas (successively) from the sum obtained in step (ii) the previous step as far as each of the six aṅkas is less than the remainder obtained in each case. Those, among the six aṅkas, which can thus be subtracted are called śuddha saṅkhyās. The one which cannot be subtracted further is called aśuddha saṅkhyā. The remainder, obtained upto here is divided by aśuddha saṅkhyā. To the obtained result add the number of śuddha sankhyās. Subtract the laghu from this result. Multiply by 3 and by bhabhoga ghaṭī (i.e., the total duration of the nakṣatra of the day). Divide this product by 8. From this result we can obtain the middle time of the pāta (elapsed or yet to take place).

Example : The remiander obtained from Śloka 7 is $0^\circ\ 33'\ 31''$. Dividing this by 5, we get laghu $0^\circ\ 6'\ 35''$. The first of the six aṅkas obtained from Ślokas 9 and 10 is 14. Now, $0^\circ\ 6'\ 35'' \times 14 = 1|32$. Adding the spaṣṭa śara $43|49$ aṅgulas to the above, we get $45|21$. Now, subtracting the previously obtained six aṅkas successively we get as follows : The first

number is 14. Now, $45|21 - 14 = 31|21$. Subtracting the second number 15 from the remainder, $31|21 - 15 = 16|21$. The next of the six aṅkas is 17 which cannot be subtracted from $16|21$. Therefore, the aśuddha saṅkhyā is 17. Dividing the remainder $16|21$ by 17, we get $0|57|42$. The number of śuddha saṅkhyās is 2 (i.e., 14 and 15) and adding this to the previous result we get $2|57|42$. Subtracting laghu $0|6|35$ from this, we have $2|51|07$. Multiplying this by 3 times we get 8|33|24. Again, multiply this result by the total duration of the day's nakṣatra (i.e., 8|33|24 × 62|55) we get $538|21$.

Dividing by 8, we get $67|17$ gh. Now, the already obtained (from Śloka 1) madhya krānti sāmya kāla is $45|50$ gh. Adding $67|17$ (since pāta is gamya) to $45|50$ gh., we get $53|07$ gh. (of the next day) i.e., Vaiśākha śukla saptamī, Saturday as the pāta madhya kāla i.e., the middle of the pāta.

Śloka 13 : The half-duration (sthiti) of the pāta is obtained by dividing 122 by the aśuddha saṅkhyā obtained earlier. Now, this sthiti is added to or subtracted from the pāta madhya kāla (the middle of the pāta kāla) to get repectively the ending and the beginning of the pāta.

Example : The aśuddha saṅkhyā is 17. Dividing 122 by 17, we get $7|10$ gh. The pāta madhya kāla is $53|07$ gh. Therefore the end (nirgama) of pāta = $53|07 + 7|10$ = $60|17$ gh. i.e., 17 vighaṭīs after the sunrise next

day (Sunday). The beginning (praveśa) of pāta is $53|07-7|10 = 45|57$ gh. on Saturday.

In case all the six aṅkas are śuddha and then the next three aṅkas must be considered and dealt with as explained earlier.

Śloka 14 : In the case of vyatīpāta and vaidhṛti pāta the sāyana Ravi is subtracted respectively from 6 and 12 rāśis to get the sāyana Candra (approximately). From the kalās equivalent of ghaṭīs, the corresponding motion of the Sun is determined and added to the sāyana Ravi to get his position at the pāta. Similarly, the true sāyana Candra and Rāhu are also obtained, by their proportion (cālanam), at the pāta madhya.

Example : At the mean instant of approximate equality of the declinations of the Sun and the Moon i.e., at $45|50$ gh., the sāyana Ravi is $1^R\ 20^\circ\ 32'\ 31''$. The interval between this instant and that of the actual pāta (when declinations are equal) is $67|17$ gh.

Considering this interval in ghaṭīs as kalās (i.e., assuming that the Sun moves at the rate of 1° per day) and adding to the earlier (sāyana) Ravi, we get his position at the actual instant of the pāta. Thus, the sāyana Ravi at the pāta = $1^R\ 20^\circ\ 32'\ 31'' + 1^\circ\ 07'\ 17'' = 1^R\ 21^\circ\ 39'\ 48''$. Similarly, at the mean instant (of krānti sāmya), the sāyana Candra = 360° – sāyana Ravi = $10^R\ 9^\circ\ 27'\ 29''$ (for vaidhṛti pāta). Now, adding the proportionate motion of the Moon for $67|17$ gh. we get the sāyana Moon at the true pāta as $10^R\ 23^\circ\ 43'$. Similarly, Rāhu is $0^R\ 25^\circ\ 7'\ 3''$ at the pāta, Ravi

krānti = $18^\circ\ 30'\ 57''$, Candra krānti = $13^\circ\ 50'\ 10''$, Virāhu Candra = $9^R\ 28^\circ\ 35'\ 57''$, śara = $44|55$, hāra = $41|39|19$.

$\therefore$ Spaṣṭa śara = $44|55 - \dfrac{44|55}{41|39|19} = 43|50|18$.

Dividing this by 10, we get $4^\circ\ 23'\ 01''$.

Corrected krānti of the Moon = $13^\circ\ 50'\ 10'' + 4^\circ\ 23'\ 01'' = 18^\circ\ 13'\ 11''$. Since the difference in the declinations of the Sun and Moon is only in kalās, it can be ignored.

CHAPTER 15

PAÑCĀṄGA CANDRA GRAHAṆĀNAYANAM

(Lunar Eclipse from Pañcāṅga)

Obtaining of the tithi, true positions of the Sun, the Moon, their diameters and Rāhu is explained.

Śloka 1 : Adding to the māsagaṇa half of itself we get dina (of tithi) and the same value along with one-third the māsagaṇa gives the ghaṭīs. Add to this the cakra times the dhruvaka $5^{d}\ 9^{gh}\ 36^{vig}$ and the kṣepaka $2^{d}\ 3^{gh}$.

Let M be the māsagaṇa. Then the dina etc. of the tithi is given by

$$\left[M+\frac{M}{2}\right]\text{days}+\left[\left(M+\frac{M}{2}\right)+\frac{M}{3}\right]\text{gh.}+(C\times D)+K$$

where C is the cakras (elapsed), D the dhruvaka (for a cakra) and K the kṣepaka. It is given that $D=5^{d}\ 9^{gh}\ 36^{vig}$ and $K=2^{d}\ 3^{gh}$ [refer to Māsagaṇadhikāra (Chapter 7), Śloka 3].

Remark : In GL, one cakra = 11 solar years = $11\times 12=132$ solar months. One adhika (intercalary) month occurs once in $32\cdot 26$ solar months. Therefore, the number of (elapsed) adhika māsas in a cakra of 11 solar years is $132/32\cdot 26=4$ (considering the integer quotient). Thus, the number of lunar months (Cāndra māsas) is 132 + 4 = 136 in a cakra. Accord-

ing to the Sūryasiddhānta, in a kalpa the number of Cāndramāsas is 53433336000. The number of civil days (sāvana dinas) in a Kalpa is 1577917828. Therefore, the number of civil days in 136 lunar months, by proportion, is $1577917828 \times 136/53433336000 =$ $4016^{d}\ 9^{gh}\ 36^{vig}$. That is, one cakra = $4016^{d}\ 9^{gh}\ 36^{vig}$. Now, removing the multiples of 7, we get $5^{d}\ 9^{gh}\ 36^{vig}$. This is the dhruvaka for a cakra.

The kṣepaka for the māsagaṇa is given as $2^{d}\ 3^{gh}$. This means that on the epochal day viz., March 19, 1520 A.D. (Julian) it was a Monday (hence 2^{d} counting from Sunday) and the mean end of Amāvāsyā (new moon) i.e., the conjuction of the Sun and the Moon took place at 3 gh. from the mean sunrise. At the mean sunrise that day, we have mean Sun – mean Moon = $349^{\circ}\ 41' - 349^{\circ}\ 06' = 35'$. Mean daily motion of (Moon – Sun) = $790'\ 35'' - 59'\ 08'' = 731'\ 27''$. Therefore, for the conjunction, the time required = $(35'/731'\ 27'') \times 60 \text{ gh.} \approx 3 \text{ gh.}$ Hence the kṣepaka for the mean conjuction of the Sun and the Moon is taken as $2^{d}\ 3^{gh}$ i.e., 3^{gh} after the mean sunrise on Monday.

Example : Given date is Śa. śa. year 1534, Kārtika Śukla 15 (Pūrṇimā), Thursday.

Cakra = 8, Māsagaṇa, M = 57.

Then, we have

$$(M + M/2) \text{ days} + [(M + M/2) + M/3] \text{ gh.} + (C \times D) + K$$

$$= (57 + 57/2) \text{ days} + [(57 + 57/2 + 57/3)] \text{ gh.} + [8 \times 5^{d}\ 9^{gh}\ 36^{vig}] + [2^{d}\ 3^{gh}]$$

$= 4^{d}\ 34^{gh}\ 18^{vig}$ (removing the multiples of 7). The deśāntara correc-

tion for the place is $+48^{vig.}$. Therefore, we get i.e., $35^{gh}\ 06^{vig}$ after the mean sunrise on Thursday.

Śloka 2 : Now, the dhruvaka of nakṣatra is explained.

(1) Multiply the cakra dhruvaka $D = 0|7|28$ by the elapsed cakra C.

(2) Add the kṣepaka $K = 48^{gh}$ to the above.

(3) Subtract the result of (2) from 27.

(4) Add $2|11$ times māsagaṇa to the result of (3).

This gives the nakṣatra dhruvam.

Example : Māsagaṇa = 57, Cakra = 8

Nakṣatra dhruvam

$= 27 - (0|7|28 \times \text{Cakra}) + 48^{gh.} + (2|11) \times$ Māsagaṇa

$= 14|39|16$

(removing the multiples of 27).

Śloka 3 : Candra's mandakendra (anomaly from the apogee) is called piṇḍa (or vṛtta). The method of obtaining the piṇḍam is explained.

(1) Multiply $21|5|9$ by Cakra.

(2) Add ($2\times$Māsagaṇa) days + (Masagaṇa/2) gh. to the result of (1)

(3) Add $14^{d}\ 9^{gh}$ to the result of (2)

(4) Remove the multiples of 28 from the days. The balance gives the piṇḍam.

Example : Māsagaṇa = 57, Cakra = 8.

Therefore, we have

(1) $21|5|9 \times 8 = 168^{d}\ 41^{gh}\ 12^{vig}$

(2) $(2 \times 57)^{t} + (57/2)^{gh}$

$$= 114^{t}\ 28^{gh}\ 30^{vig}$$

The superscript t denotes tithis.

Adding this to (1), we get $283^{t}\ 09^{gh}\ 42^{vig}$

(3) $283^{t}\ 09^{gh}\ 42^{vig} + 14^{d}\ 9^{gh}$

$$= 297^{t}\ 18^{gh}\ 42^{vig}$$

Removing the multiples of 28 from the days (tithis), we get

Candra piṇḍam = $17^{t}\ 18^{gh}\ 42^{vig}$

Remark : We have Moon's mean daily motion = $790'\ 35''$ and the mean daily motion of Moon's apogee (mandocca) = $6'\ 41''$. Their difference = $790'\ 35'' - 6'\ 41'' = 783'\ 54''$.

That is, to cover $783'\ 54''$, Moon's anomaly requires 1 civil day.

To cover 360°, the civil days required is $\dfrac{360 \times 60}{783'\ 54''}$.

Therefore, the number of lunar days (tithis) for Moon's anomaly to complete one revolution of 360° is

$$\frac{360\times 60\times 30}{783'\,54''\times 29.53} = 27^{t}.993001$$

which GL has taken as 28 tithis.

(Note : 1 lunar month of 30 tithis ≈ 29.53 civil days).

Śloka 4 : Obtaining the ghaṭīphalam from the nakṣatra of the Sun :

The ghaṭīphalams of the Sun's mandaphala for the six nakṣatras from Aśvinī to Ārdra are respectively 11, 10, 8, 6, 4, 2 ghaṭīs and are positive; then for the 14 nakṣatras from Punarvasu (Āditeya) to Pūrvāṣāḍhā these are respectively 0, 3, 5, 7, 9, 10, 11, 10, 10, 9, 8, 6, 3, 0 ghaṭīs and negative. Further, for the last 7 nakṣatras viz. Uttarāṣāḍhā to Revatī, the ghaṭīphalams are respectively 2, 4, 6, 8, 9, 10, 11 ghaṭīs and positive.

Explanation : When the true Sun is at the end of Aśvinī (i.e., $13^\circ\,20'$), the mandocca of the Sun being constant at 78°, the mandaphalam is approximately $118'$. The relative motion of the Moon with respect to the Sun, to cover $118'$ is given by

$$\frac{118\times 60}{790'\,35''-59'\,8''}\ \text{gh.} = 9.679\ \text{gh.}$$

taken approximately as 11 gh. in GL. Similarly, at the end of other nakṣatras the ghatīphalams are calculated.

Śloka 5 : Obtaining the mean and then the true sūryanakṣatra is explained as follows.

(1) Multiply the given tithi (iṣṭa tithi) by 4 and divide by 12.

(2) Add the result of (1) to ($4\times$ iṣṭatithi).

(3) Add dhruva (in gh.) to (2). This is called sūrya nakṣatra ghaṭī.

(4) Find the difference of the nakṣatra ghaṭīs of the nakṣatra in which the Sun is positioned and that of the next.

(5) Multiply only the ghaṭīs etc. of results of (3) and (4) and divide the product by 60.

(6) Add or subtract the result of (5) to or from the ghaṭīphalam of the current nakṣatra. This gives the spaṣṭa sūrya nakṣatra ghaṭikā.

Example : (Refer to the example under Ślokas 1 and 2)

Suppose the iṣṭa tithi = 15. Now, we have

(1) $15\times 4=60$, $60/12=5$

(2) $60+5=65$ gh.

(3) The nakṣatra dhruvaka = $\overset{n}{14}|\overset{gh}{39}|\overset{vig}{16}$ obtained in the example under śloka 2. Adding 65 gh. to the dhruvaka, we get $\overset{n}{15}|\overset{gh}{44}|\overset{vig}{16}$. This is the sūrya nakṣatra ghaṭī.

(4) Now, the gata (elapsed) nakṣatras are 15 and currently the Sun is in the 16th nakṣatra i.e., Viśākhā. Its very next nakṣatra is Anurādhā. From Śloka 4, their respective ghaṭīphalams are 9 and 8 (both negative). The difference of their values is – 1 $[\text{i.e.}, -9-(-8)]$ gh.

(5) $\left(44^{gh.}\ 16^{vig.}\right)(-1)=-44^{gh.}\ 16^{vig.}$

$$\therefore \left(-44^{gh.}\ 16^{vig.}\right)/60=-0^{gh.}\ 44^{vig.}$$

(6) Spaṣṭa Sūrya nakṣatra ghaṭikā = $9^{gh.} - 0^{gh.}\ 44^{vig.} = 8^{gh.}\ 16^{vig.}$ Since the ghaṭīphala $9^{gh.}$ is subtractive, $8^{gh.}\ 16^{vig.}$ is also subtractive. Now, applying this correction to the sūrya nakṣatra (with gh. etc.) obtained in (3), viz. $15^{n}\ 44^{gh.}\ 16^{vig.}$, we get $15^{n}\ 44^{gh.}\ 16^{vig.} - 8^{gh.}\ 16^{vig.}$ = $15^{n}\ 36^{gh.}\ 0^{vig.}$

i.e., the corrected ghaṭikā of the running Viśākhā nakṣatra is 36 gh.

Śloka 6 : Add the iṣṭa tithi to the piṇḍam (obtained earlier). If the sum exceeds 28, remove its multiples.

Now, the piṇḍaphalam (from the tithi) is discussed. The piṇḍa ghaṭīs for tithis from 1 to 14 are shown in Table 15.1. For tithis from 1 to 14 the piṇḍa ghaṭīs must be taken as positive.

If the tithi is greater than 14 then subtract it from 28 and consider the balance tithi and as negative. These are shown in Table 15.1.

Table 15.1 Piṇḍa ghaṭikās for tithis

Tithi	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Piṇḍa Ghaṭikā	5	10	15	19	22	24	25	24	22	19	15	10	5	0

Example : Previously obtained (from the example under Śloka 3)

Piṇḍa = $17^{t}\ 18^{gh.}\ 42^{vig.}$ Iṣṭatithi = 15

Adding we get $32^{t}\ 18^{gh.}\ 42^{vig.}$. Since this exceeds 28, removing the multipes of 28, we get $4^{t}\ 18^{gh.}\ 42^{vig.}$. From Table 15.1, for the tithi

4, we get correspondingly 19 as piṇḍa ghaṭikās. From this we have to find the correction to it (spaṣṭīkaraṇa) as follows :

For the balance of $18^{gh.}\ 42^{vig.}$, we have to find proportionate piṇḍa ghaṭikā. The next (agrima) piṇḍaghaṭikā is 22. The difference is 22 – 19 = 3. Therefore, for the balance of $18^{gh.}\ 42^{vig.}$, we get $\dfrac{18^{gh.}\ 42^{vig.} \times 3}{60}$ = $0^{gh.}\ 56^{vig.}$. This is additive since $22 > 19$.

Therefore, the spaṣṭa piṇḍa ghaṭikā

$$= 19^{gh.} + 0^{gh.}\ 56^{vig.} = 19^{gh.}\ 56^{vig.}$$

Śloka 7 : Here, the day etc. of spaṣṭa tithi is explained.

(1) Consider the previously obtained vārādika (day etc.). Add the iṣṭa tithi to the number in the dina position.

(2) Subtract from the ghaṭī place the iṣṭa tithi taken as ghaṭīs.

This gives madhyama tithi.

(3) Add or subtract Raviphalam and Piṇḍaphalam ghatīs to or from the madhyama tithi (from step 2) as the cases may be.

Example : In the example under Śloka 1 (from the māsagaṇa) we have Vārādika = $4^{d}\ 35^{gh}\ 06^{vig.}$, Iṣṭa tithi = 15 (i.e., pūrṇimā)

From step (2), we get

Madhyama Tithi = $(4+15)^{d},\ (35-15)^{gh.},\ 06^{vig.} = 19^{d}\ 20^{gh.}\ 06^{vig.}$

Removing multiples of 7 from 19^{d}, we get the balance $5^{d}\ 20^{gh.}\ 06^{vig.}$

Ravināḍī = $8^{gh.}\ 16^{vig.}$ [obtained in (6) under Śloka 5]

Since it is subtractive, we have $5^{d}\ 20^{gh.}\ 06^{vig.} - 8^{gh.}\ 16^{vig.} = 5^{d}\ 11^{gh.}\ 50^{vig.}$.

Again, since the piṇḍaghaṭī $19^{gh.}\ 56^{vig.}$ is additive, we have

corrected vārādi of the spaṣṭa tithi

$$= 5^{d}\ 11^{gh.}\ 50^{vig.} + 19^{gh.}\ 56^{vig.} = 5^{d}\ 31^{gh.}\ 46^{vig.}$$

i.e., the 15th tithi ends at $31^{gh.}\ 46^{vig.}$ on Thursday.

Śloka 8 : Here obtaining of the ghaṭikās etc. of the nakṣatra is explained.

(i) The sum of the partless (avayava rahitam) i.e., integer values of the nakṣatra and tithi dhruvakas is considered. Remove the multiples of 27 from the sum. The remainder gives the number of the current nakṣatra.

(ii) Multiply the number of tithi (tithi saṅkhyā) by 2 and subtract from it (i.e., twice tithi) one-sixth of it.

(iii) Add to the above result the tithi ghaṭikās.

(iv) Then take the sūrya ghaṭīphalam (obtained in Śloka 5) and subtract from or add to the above result respectively according as it is additive or subtractive.

(v) From this subtract the nakṣatra dhruva ghaṭī. This gives the nakṣatra ghaṭikās.

Note : In step (v), if the nakṣatra dhruva ghaṭī (x) is greater than the value obtained (y) in step (iv), then subtract x from 60 and add the

resultant to y i.e., obtain $y+(60-x)$ or $(y-x)+60$ gh. In other words, if $(y-x)$ is negative then add 60 to it. In this case add 1 to the nakṣatra number.

On the other hand if $x>60$, then subtract 60 from it and then subtract the difference from y and subtract 1 from the nakṣatra number.

Example : Nakṣatra saṅkhyā = 14 (obtained in the nakṣatra dhruvaka in the example under Śloka 2). The iṣṭa tithi saṅkhyā = 15

$\therefore$ Nakṣatra saṅkhyā + Tithi saṅkhyā = 14 + 15 = 29

Since the sum exceeds 27, subtracting 27 from it, the remainder is the current nakṣatra saṅkhyā = 2 i.e., Bharaṇī nakṣatra.

Now, tithi ghaṭikās = $31|46$ gh. (of the corrected Vārādi of spaṣta tithi obtained as $5^{d}\ 31^{gh.}\ 46^{vig.}$ in the example under Śloka 7). We have

Tithi saṅkhyā = 15. Therefore

$$2\times \text{Tithi}-\frac{1}{6}(2\times \text{Tithi}) = \frac{5}{3}\text{Tithi}=25 \text{ gh.}$$

Adding the above result to the earlier obtained tithi ghaṭikās, we get

$$31^{gh.}\ 46^{vig.}+25^{gh.} = 56^{gh.}\ 46^{vig.}$$

From the example under Śloka 5, we have

Sūrya ghaṭīphalam = $-8|16$ gh.

Considering the opposite sign, we get $56|46 \text{ gh.}+8|16 \text{ gh.}=65|02 \text{ gh.}$

We have nakṣatra dhruva nāḍī = 39|16 gh. (see example under śloka 2).

Therefore, the current nakṣatra ghaṭikā = $65|02 - 39|16 = 25|46$ gh.

The note under the above śloka is not applicable here.

Thus, for the given day (i.e., the pūrṇimā) the current nakṣatra with ghaṭīs etc. is $2^{n}|25^{gh.}|46^{vig.}$ i.e. Bharaṇī ends at 25gh 46 vig.

Śloka 9 : Now, obtaining of yoga from the nakṣatras of the Sun and the Moon is explained.

(1) The sum of the Sūryanakṣatra and Candranakṣatra gives the yoga.

(2) The difference between the ghaṭikās of the Sūrya and Candra nakṣatras is known as antara yoga ghaṭikā and it gives the ghaṭikās of the current yoga.

(3) If the ghatikā of the Sūryanakṣatra exceeds that of the Candra nakṣatra, then add 1 to the yoga saṅkhyā [obtained in (1) above] and in that case yoga ghaṭikā is 60 – antara yoga ghaṭīkā.

Example : Sūrya nakṣatra = 15, Candra nakṣatra = 2

Adding, the yoga saṅkhyā = 15 + 2 = 17 i.e., Vyatīpāta yoga.

We have Sūrya nakṣatra ghaṭikā = $36|0$

Candra nakṣatra ghaṭikā = $25|46$

$\therefore$ antara ghaṭikā = $36|0 - 25|46 = 10|14$

In this case, the sūrya nakṣatra ghaṭikā > Candra nakṣatra ghaṭikā (i.e., $36 > 25|46$). Therefore, adding 1 to the earlier obtained yoga

saṅkhyā, we get $17+1=18$ i.e., the current running yoga, Varīyān and the yoga ghaṭikā = $60-10|14 = 49|46$ ghaṭīs.

After this Parigha yoga commences.

Śloka 10 : Now, the method of obtaining Rāhu at the end of pūrṇimā is explained.

(1) Multiply the cakra dhruvaka $7^R\ 2^\circ\ 50'$ by cakra.

(2) Multiply the māsa dhruvaka $0^R\ 1^\circ\ 34'$ by the māsagaṇa.

(3) Add the results of (1) and (2) and remove the multiples of 12. The resultant is subtracted from 12.

(4) Add 27° (kṣepaka) to (3). This gives Rāhu at the end of the pūrṇimā.

Example : Cakra = 8, Māsagaṇa = 57.

(1) $7^R\ 2^\circ\ 50' \times 8 = 56^R\ 22^\circ\ 40'$

(2) $0^R\ 1^\circ\ 34' \times 57 = 2^R\ 29^\circ\ 18'$

(3) Adding (1) and (2), we have

$$56^R\ 22^\circ\ 40' + 2^R\ 29^\circ\ 18' = 59^R\ 21^\circ\ 58'$$

Removing the multiples of 12, we get $11^R\ 21^\circ\ 58'$. Subtracting this from 12^R, we have $0^R\ 08^\circ\ 02'$.

(4) Adding 27° to (3), we get $27^\circ + 0^R\ 08^\circ\ 02' = 1^R\ 5^\circ\ 02'$

i.e., Rāhu = $1^R\ 5^\circ\ 02'$

Śloka 11 : Obtaining of the Sun's position is explained.

(1) Multiply the elapsed nakṣatra (with gh. and vig.) by 4 and divide by 9. This gives the position of the Sun at the end of iṣṭa tithi (pūrṇimā for lunar eclipse).

(2) If the bhuja of the difference between the Sun at the end of the parva (i.e., parvānta kāla Ravi) and Rāhu is less than 14° then there is a possibility of a lunar eclipse.

Example : Ravi bhukta nakṣatra = $15|36|0$. Multiplying by 4 and dividing by 9, we get $(15|36|0)\times 4/9 = (62|24|0)/9$; the quotient = 6 rāśis and

remainder = $(8|24|0)/9 = 264^\circ/9 = 29^\circ\ 20'$.

Therefore, Ravi = $6^R\ 29^\circ\ 20'$ at the end of pūrṇimā.

Now, Ravi – Rāhu = $6^R\ 29^\circ\ 20' - 1^R\ 5^\circ\ 02' = 5^R\ 24^\circ\ 18'$

Bhuja of the above difference = $6^R - (5^R\ 24^\circ\ 18') = 5^\circ\ 42' < 14^\circ$.

Therefore, there is a possibility of the lunar eclipse on that day.

Śloka 12 : Obtaining : grāsa of Candra.

(1) Consider the difference between the gata (elapsed) and the eṣya (to be elapsed) piṇḍaghaṭīkās.

(2) Add 12 to $\frac{1}{4}^{th}$ of the above result.

(3) Subtract bhujāmśa of vyagvarka i.e., (Sun – Rāhu) from the result of item (2).

(4) Consider $\frac{1}{2}$ of the above.

(5) Add the results of items (3) and (4). The sum gives candragrāsa.

Example : The gata piṇḍa = 19, eṣya piṇḍa = 22

[obtained from Table 15.1 for the example under Śloka 6].

(1) Difference between the gata and the eṣya piṇḍas = 22 – 19 = 3.

(2) $\frac{1}{4}\times 3+12 = 0|45+12|0 = 12|45$

(3) Bjujāṃśa of vyagvarka = $5^{\circ}\ 42'$ (see the example under Śloka 11).

Now, $12|45-5|42=7|03$

(4) $\frac{1}{2}(7|03) = 3|16|30$

(5) $\therefore$ Candra grāsa = $7|03+3|16|30 = 10|19|30$ aṅgulas

Śloka 13 : Obtaining of the diameters of the Moon and earth's shadow.

(1) Consider the difference between the elapsed (gata) and the balance of the eṣya piṇḍa.

(2) Add $\frac{1}{6}^{\text{th}}$ of the above result to $10|40$ aṅgulas. The result is the bimbam (diameter) of the Moon.

(3) The bhūbhā bimbam (diameter of the earth's shadow) is given by adding to or subtracting from 27 three-fifths of the difference between the gata and eṣya piṇḍas.

Note : $10|40$ aṅgulas and 27 aṅgulas are the mean diameters of the moon and the earth's shadow cone.

If P_1 and P_2 are respectively the earlier and the latter piṇḍa ghaṭīs (in Table 15.1 under Śloka 6), then

(i) Candra bimbam = $|P_2 - P_1|/6 + 10|40$ aṅgulas

(ii) Bhūbhā bimbam = $(3/5)\ |P_2 - P_1| + 27$ aṅgulas

Example : $P_1 = 19$ and $P_2 = 22$

$\therefore$ Candra bimbam = $\frac{3}{6} + 10|40$ = $0|30 + 10|40$ = $11|10$ aṅgulas

Bhūbhā bimbam = $\left(\frac{3}{5} \times 3\right) + 27$ = $1|48 + 27$ = $28|48$ aṅgulas

Śloka 14 : Obtaining of vārādi (week day etc.) of every lunar month.

(1) Add $1|31|50$ to the vārādi of the current lunar month to get that of the next lunar month (agrima māsa).

(2) Add 2 to the piṇḍa and $2^{d}\ 11^{gh}$ to the nakṣatra dhruvaka respectively to get those of the next lunar month.

(3) Subtract $94'$ (i.e., $1^\circ\ 34'$) from the current month's dhruvaka of Rāhu to get that of the succeeding month.

Example : (i) In the given year, for the Kārtika month, vārādi = $4^{d}|35^{gh}|06^{vig}$

Adding $1^{d}|31^{gh}|50^{vig}$ to the above, we get

$$4^{d}|35^{gh}|06^{vig} + 1^{d}|31^{gh}|50^{vig} = 6^{d}|06^{gh}|56^{vig}$$

as the vārādi of the succeeding lunar month viz. Mārgaśīrṣa.

(ii) At the beginning of the Kārtika month in the given year, we have

Piṇḍa dhruvaka = $17^{d}|18^{gh.}|42^{vig.}$

Adding 2^{d} we get

the piṇḍa dhruvaka as $19^{d}|18^{gh.}|42^{vig.}$ at the beginning of the next month.

(iii) At the beginning of the Kārtika month of the given year, we have

nakṣatra dhruvaka = $14^{n}|39^{gh.}|16^{vig.}$

Adding $2^{n}|11^{gh.}$ we get

$16^{n}|50^{gh.}|16^{vig.}$ as the nakṣatra dhruvaka at the beginning of the next month viz. Mārgaśīrṣa.

(iv) At the beginning of current lunar month (Kārtika), we have

Rāhu = $1^{R}\ 5^{\circ}\ 2'$. Subtracting $1^{\circ}\ 34'$ from Rāhu, we get

Rāhu = $1^{R}\ 3^{\circ}\ 28'$ at the beginning of the next month viz., Mārgaśīrṣa.

CHAPTER 16

UPASAṂHĀRĀDHIKĀRA

(Concluding Chapter)

Finding the ahargaṇa for a date, prior to the Grahalāghavam epoch.

Ślokas 1 and 2 : Subtract the given śaka year from 1442 and by dividing the remainder by 11 we get the cakras (as quotient). By subtracting the elapsed months (counted from Caitra) from the product of 12 and the remainder obtained above, keep this in two separate places. Add twice the cakra and 24 to one of them and then divide by 33 to get adhikamāsas. Add this to the number kept separately. Multiply the result by 30 and subtract the given elapsed tithi from the product. To this result add $\frac{1}{6}^{th}$ of cakra.

Subtract $\frac{1}{64}^{th}$ of the above sum (kṣaya tithis) from itself. This gives the ahargaṇa (of a date prior to the beginning of the śaka year 1442 i.e., 1520 A.D. March 19).

Explanation : Suppose the date given is Śā. Śa. year Y, lunar month M, tithi T (all elapsed) prior to the GL epoch viz., March 19, 1520 A.D. (Julian).

(i) Consider $1442-Y$

(ii) Cakras C = Quotient of $(1442-Y)/11$

and the remainder be R.

(iii) Find $(12R - M) \equiv X$, say

(iv) Consider $(X + 2C + 24)$ and divide it by 33.

Let A = Quotient of $\dfrac{(X + 2C + 24)}{33}$

which gives the adhikamāsas (intercalary months)

(v) $X + A$ is the number of lunar months. Multiplying this by 30 and subtracting the current tithi, we get $(X + A) \times 30 - T$.

(vi) Obtain $30(X + A) - T + C/6 \equiv Z$, say

(vii) $\frac{1}{6}^{th}$ of Z is the number of kṣaya tithis. This is to be subtracted from Z. We get $Z - Z/64$.

This gives the ahargaṇa of a given date before the GL epoch.

Example : Śā. Śa. $1441 \equiv Y$

(i) $1442 - Y = 1442 - 1441 = 1$.

(ii) Cakras, C = Quotient of $(1442 - 1441)/11 = 0$.

Remainder, $R = 1$

(iii) $X = 12R - M = 12(1) - 3 = 9$

where $M = 3$, the months elapsed from Caitra.

(iv) $X + 2C + 24 = 9 + 2(0) + 24 = 33$.

Dividing the above by 33, we get the number the adhikamāsas, $A = 1$.

(v) $X + A = 9 + 1 = 10 \equiv$ Māsagaṇa

We have $(X + A)30 - T = (10)(30) - 14 = 300 - 14 = 286$

where $T = 14$, the given (elapsed) tithi.

(vi) $\frac{1}{6}^{th}$ of Cakra, $C/6 = 0$ (quotient) $\therefore Z = 286$

(vii) $Z/64 = 286/64$ gives the quotient 4, the kṣaya tithis. Subtracting this from Z we get $286 - 4 = 282$.

This is the ahargaṇa of the given date before the epoch of GL and hence negative. The negative sign indicates that the date is prior to the GL epoch. In fact, the corresponding Christian date is June 11, 1519 (J), Saturday.

Weekday from cakra and ahargaṇa of a date prior to the GL epoch.

Multiply the cakra C by 5 and add the ahargaṇa A to get $5C + A$. Divide this by 7. If the remainder $R = 0$, then it is Monday, $R = 1$: Sunday etc. (backwards).

Example : Cakra = 0, ahargaṇa = 282 prior to the GL epoch. (In the modern convention, actually, the ahargaṇa = – 282). Dividing 282 by 7 we get the remainder as 2. Counting backwards from 0 as Monday (i.e., of the GL epoch), the remainder 2 represents Saturday (Śani vāsara).

Note : Commentator Viśvanātha gives the weekday in his example as Wednesday.

Śloka 3 : Obtaining the mean positions of planets from the given ahargaṇa (prior to the GL epoch).

The ahargaṇa generated mean motion of a planet is subtracted from the kṣepaka (epochal position) and to it is added the product of cakra and dhruvaka. This gives the mean position of the planet.

Example : For Ravi, dhruvaka $D = 0^R\ 1^\circ\ 49'\ 11''$ and kṣepaka, $K = 11^R\ 19^\circ\ 41'$. For the given date, $C = 0$, $A = 282$.

Ahargaṇa generated motion of Ravi = $9^R\ 7^\circ\ 56'\ 26'' \equiv M$, say

$\therefore$ Mean position of Ravi

$$= K - M + (C \times D) = 11^R\ 19^\circ\ 41'\ 0'' - 9^R\ 7^\circ\ 56'\ 26'' = 2^R\ 11^\circ\ 44'\ 34''$$

(since C = 0).

Similarly, other mean planets are determined.

Śloka 4 : The earlier preceptors very proudly rose to the peak of their fame though only in a few places they did calculations without using sine etc. But I have made the calculations of the entire siddhānta (astronomy) simple (lāghava) by omitting sine etc. throughout. I have my intelligence (and knowledge) enriched only from their works and hence I do not exhibit pride (of my achievement).

Śloka 5 : In the western region, at a town called Nandigrāma there lived Keśava of Kauśika gotra who was an expert in all branches of knowledge praised by his children and disciples. His son Gaṇeśa, by his service at the feet of Keśava, obtained knowledge and composed this handbook which is decorated with several metrical verses and clarity.

APPENDIX 1

Manda Equations of Kuja, Budha, Guru, Śukra, Śani according to Sūrya Siddhānta

Anom.	Kuja			Budha			Guru			Śukra			Śani		
Deg.	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	12	29	0	5	0	0	5	30	0	2	0	0	8	10
2	0	24	58	0	9	58	0	10	59	0	3	59	0	16	19
3	0	37	24	0	14	56	0	16	28	0	5	58	0	24	28
4	0	49	49	0	19	53	0	21	56	0	7	57	0	32	36
5	1	2	12	0	24	49	0	27	24	0	9	55	0	40	43
6	1	14	33	0	29	44	0	.32	50	0	11	52	0	48	48
7	1	26	51	0	34	38	0	38	16	0	13	49	0	56	53
8	1	39	7	0	39	30	0	43	40	0	15	46	1	4	56
9	1	51	20	0	44	21	0	49	4	0	17	42	1	12	58
10	2	3	30	0	49	10	0	54	26	0	19	37	1	20	58
11	2	15	37	0	53	58	0	59	47	0	21	31	1	28	56
12	2	27	40	0	58	44	1	5	6	0	23	25	1	36	52
13	2	39	40	1	3	29	1	10	24	0	25	18	1	44	46
14	2	51	35	1	8	11	1	15	41	0	27	10	1	52	38
15	3	3	27	1	12	52	1	20	55	0	29	1	2	0	28
16	3	15	14	1	17	31	1	26	8	0	30	52	2	8	15
17	3	26	57	1	22	8	1	31	19	0	32	41	2	15	59
18	3	38	35	1	26	42	1	36	28	0	34	30	2	23	41
19	3	50	8	1	31	15	1	41	35	0	36	18	2	31	20
20	4	1	36	1	35	45	1	46	40	0	38	5	2	38	55
21	4	12	59	1	40	13	1	51	42	0	39	50	2	46	28
22	4	24	16	1	44	38	1	56	43	0	41	35	2	53	57
23	4	35	28	1	49	1	2	1	40	0	43	19	3	1	22
24	4	46	34	1	53	22	2	6	36	0	45	2	3	8	44
25	4	57	34	1	57	40	2	11	28	0	46	43	3	16	3
26	5	8	27	2	1	55	2	16	18	0	48	24	3	23	17
27	5	19	15	2	6	7	2	21	6	0	50	3	3	30	28
28	5	29	55	2	10	17	2	25	50	0	51	42	3	37	34
29	5	40	29	2	14	24	2	30	32	0	53	19	3	44	36
30	5	50	56	2	18	28	2	35	11	0	54	55	3	51	34
31	6	1	16	2	22	29	2	39	46	0	56	29	3	58	28
32	6	11	29	2	26	27	2	44	19	0	58	3	4	5	17
33	6	21	34	2	30	22	2	48	48	0	59	35	4	12	1
34	6	31	32	2	34	13	2	53	14	1	1	6	4	18	40
35	6	41	22	2	38	2	2	57	36	1	2	35	4	25	15

APPENDIX 1 — Contd.

Anom.	Kuja			Budha			Guru			Śukra			Śani		
Deg.	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S
36	6	51	4	2	41	47	3	1	56	1	4	3	4	31	44
37	7	0	39	2	45	29	3	6	11	1	5	30	4	38	8
38	7	10	5	2	49	8	3	10	24	1	6	56	4	44	27
39	7	19	22	2	52	43	3	14	32	1	8	20	4	50	41
40	7	28	32	2	56	15	3	18	37	1	9	43	4	56	49
41	7	37	32	2	59	44	3	22	38	1	11	4	5	2	52
42	7	46	24	3	3	8	3	26	35	1	12	24	5	8	49
43	7	55	7	3	6	30	3	30	28	1	13	43	5	14	41
44	8	3	41	3	9	47	3	34	18	1	15	0	5	20	26
45	8	12	6	3	13	1	3	38	3	1	16	15	5	26	5
46	8	20	22	3	16	12	3	41	45	1	17	29	5	31	39
47	8	28	28	3	19	18	3	45	22	1	18	42	5	37	6
48	8	36	25	3	22	21	3	48	55	1	19	53	5	42	27
49	8	44	12	3	25	20	3	52	23	1	21	3	5	47	42
50	8	51	50	3	28	15	3	55	48	1	22	11	5	52	50
51	8	59	17	3	31	6	3	59	8	1	23	17	5	57	52
52	9	6	35	3	33	53	4	2	24	1	24	22	6	2	48
53	9	13	43	3	36	37	4	5	35	1	25	26	6	7	36
54	9	20	40	3	39	16	4	8	42	1	26	27	6	12	18
55	9	27	27	3	41	51	4	11	44	1	27	28	6	16	53
56	9	34	4	3	44	23	4	14	41	1	28	26	6	21	21
57	9	40	30	3	46	50	4	17	34	1	29	23	6	25	43
58	9	46	46	3	49	13	4	20	23	1	30	19	6	29	57
59	9	52	51	3	51	32	4	23	6	1	31	12	6	34	4
60	9	58	46	3	53	46	4	25	45	1	32	5	6	38	4
61	10	4	29	3	55	57	4	28	19	1	32	55	6	41	57
62	10	10	2	3	58	3	4	30	48	1	33	44	6	45	42
63	10	15	24	4	0	6	4	33	12	1	34	31	6	49	20
64	10	20	34	4	2	3	4	35	31	1	35	17	6	52	51
65	10	25	34	4	3	57	4	37	45	1	36	1	6	56	14
66	10	30	22	4	5	46	4	39	55	1	36	43	6	59	30
67	10	34	59	4	7	31	4	41	59	1	37	23	7	2	38
68	10	39	25	4	9	12	4	43	58	1	38	2	7	5	38
69	10	43	40	4	10	48	4	45	52	1	38	39	7	8	31
70	10	47	43	4	12	20	4	47	41	1	39	15	7	11	16
71	10	51	34	4	13	48	4	49	25	1	39	49	7	13	53
72	10	55	14	4	15	11	4	51	4	1	40	21	7	16	23
73	10	58	42	4	16	30	4	52	37	1	40	51	7	18	44
74	11	1	59	4	17	44	4	54	6	1	41	20	7	20	58

APPENDIX 1 — Contd.

Anom.	Kuja			Budha			Guru			Śukra			Śani		
Deg.	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S
75	11	5	4	4	18	54	4	55	29	1	41	47	7	23	4
76	11	7	57	4	19	59	4	56	47	1	42	12	7	25	2
77	11	10	39	4	21	0	4	57	59	1	42	35	7	26	51
78	11	13	8	4	21	57	4	59	6	1	42	57	7	28	33
79	11	15	26	4	22	49	5	0	8	1	43	17	7	30	7
80	11	17	32	4	23	36	5	1	5	1	43	35	7	31	33
81	11	19	26	4	24	19	5	1	56	1	43	52	7	32	50
82	11	21	8	4	24	58	5	2	42	1	44	7	7	34	0
83	11	22	38	4	25	32	5	3	22	1	44	20	7	35	1
84	11	23	56	4	26	1	5	3	57	1	44	31	7	35	54
85	11	25	2	4	26	26	5	4	27	1	44	41	7	36	39
86	11	25	57	4	26	47	5	4	51	1	44	49	7	37	16
87	11	26	39	4	27	2	5	5	10	1	44	55	7	37	45
88	11	27	9	4	27	14	5	5	24	1	44	59	7	38	6
89	11	27	27	4	27	21	5	5	32	1	45	2	7	38	18
90	11	27	33	4	27	23	5	5	35	1	45	3	7	38	22
91	11	27	27	4	27	21	5	5	32	1	45	2	7	38	18
92	11	27	9	4	27	14	5	5	24	1	44	59	7	38	6
93	11	26	39	4	27	2	5	5	10	1	44	55	7	37	45
94	11	25	57	4	26	47	5	4	51	1	44	49	7	37	16
95	11	25	3	4	26	26	5	4	27	1	44	41	7	36	39
96	11	23	56	4	26	1	5	3	57	1	44	31	7	35	54
97	11	22	38	4	25	32	5	3	22	1	44	20	7	35	1
98	11	21	8	4	24	58	5	2	42	1	44	7	7	34	0
99	11	19	26	4	24	19	5	1	56	1	43	52	7	32	50
100	11	17	32	4	23	36	5	1	5	1	43	35	7	31	33
101	11	15	26	4	22	49	5	0	8	1	43	17	7	30	7
102	11	13	8	4	21	57	4	59	6	1	42	57	7	28	33
103	11	10	39	4	21	0	4	57	59	1	42	35	7	26	51
104	11	7	57	4	19	59	4	56	47	1	42	12	7	25	2
105	11	5	4	4	18	54	4	55	29	1	41	47	7	23	4
106	11	1	59	4	17	44	4	54	6	1	41	20	7	20	58
107	10	58	42	4	16	30	4	52	37	1	40	51	7	18	44
108	10	55	14	4	15	11	4	51	4	1	40	21	7	16	23
109	10	51	34	4	13	48	4	49	25	1	39	49	7	13	53
110	10	47	43	4	12	20	4	47	41	1	39	15	7	11	16
111	10	43	40	4	10	48	4	45	52	1	38	39	7	8	31
112	10	39	25	4	9	12	4	43	58	1	38	2	7	5	38
113	10	34	59	4	7	31	4	41	59	1	37	23	7	2	38

APPENDIX 1 — Contd.

Anom.	Kuja			Budha			Guru			Śukra			Śani		
Deg.	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S
114	10	30	22	4	5	46	4	39	55	1	36	43	6	59	30
115	10	25	34	4	3	57	4	37	45	1	36	1	6	56	14
116	10	20	34	4	2	3	4	35	31	1	35	17	6	52	51
117	10	15	24	4	0	6	4	33	12	1	34	31	6	49	20
118	10	10	2	3	58	3	4	30	48	1	33	44	6	45	42
119	10	4	29	3	55	57	4	28	19	1	32	55	6	41	57
120	9	58	46	3	53	46	4	25	45	1	32	5	6	38	4
121	9	52	51	3	51	32	4	23	6	1	31	12	6	34	4
122	9	46	46	3	49	13	4	20	23	1	30	19	6	29	57
123	9	40	30	3	46	50	4	17	34	1	29	23	6	25	43
124	9	34	4	3	44	23	4	14	41	1	28	26	6	21	21
125	9	27	27	3	40	51	4	11	44	1	27	28	6	16	53
126	9	20	40	3	39	16	4	8	42	1	26	27	6	12	18
127	9	13	43	3	36	37	4	5	35	1	25	26	6	7	36
128	9	6	35	3	33	53	4	2	24	1	24	22	6	2	48
129	8	59	17	3	31	6	3	59	8	1	23	17	5	57	52
130	8	51	50	3	28	15	3	55	48	1	22	11	5	52	50
131	8	44	12	3	25	20	3	52	23	1	21	3	5	47	42
132	8	36	25	3	22	21	3	48	55	1	19	53	5	42	27
133	8	28	28	3	19	18	3	45	22	1	18	42	5	37	6
134	8	20	22	3	16	12	3	41	45	1	17	29	5	31	39
135	8	12	6	3	13	1	3	38	3	1	16	15	5	26	5
136	8	3	41	3	9	47	3	34	18	1	15	0	5	20	26
137	7	55	7	3	6	30	3	30	28	1	13	43	5	14	41
138	7	46	24	3	3	8	3	26	35	1	12	24	5	8	49
139	7	37	32	2	59	44	3	22	38	1	11	4	5	2	52
140	7	28	32	2	56	15	3	18	37	1	9	43	4	56	49
141	7	19	22	2	52	43	3	14	32	1	8	20	4	50	41
142	7	10	5	2	49	8	3	10	24	1	6	56	4	44	27
143	7	0	39	2	45	29	3	6	11	1	5	30	4	38	8
144	6	51	4	2	41	47	3	1	56	1	4	3	4	31	44
145	6	41	22	2	38	2	2	57	36	1	2	35	4	25	15
146	6	31	32	2	34	13	2	53	14	1	1	6	4	18	40
147	6	21	34	2	30	22	2	48	48	0	59	35	4	12	1
148	6	11	29	2	26	27	2	44	19	0	58	3	4	5	17
149	6	1	16	2	22	29	2	39	46	0	56	29	3	58	28
150	5	50	56	2	18	28	2	35	11	0	54	55	3	51	34
151	5	40	29	2	14	24	2	30	32	0	53	19	3	44	36
152	5	29	55	2	10	17	2	25	50	0	51	42	3	37	34

APPENDIX 1 — Contd.

Anom.	Kuja			Budha			Guru			Śukra			Śani		
Deg.	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S
153	5	19	15	2	6	7	2	21	6	0	50	3	3	30	28
154	5	8	27	2	1	55	2	16	18	0	48	24	3	23	17
155	4	57	34	1	57	40	2	11	28	0	46	43	3	16	3
156	4	46	34	1	53	22	2	6	36	0	45	2	3	8	44
157	4	35	28	1	49	1	2	1	40	0	43	19	3	1	22
158	4	24	16	1	44	38	1	56	43	0	41	35	2	53	57
159	4	12	59	1	40	13	1	51	42	0	39	50	2	46	28
160	4	1	36	1	35	45	1	46	40	0	38	5	2	38	55
161	3	50	8	1	31	15	1	41	35	0	36	18	2	31	20
162	3	38	35	1	26	42	1	36	28	0	34	30	2	23	41
163	3	26	57	1	22	8	1	31	19	0	32	41	2	15	59
164	3	15	14	1	17	31	1	26	8	0	30	52	2	8	15
165	3	3	27	1	12	52	1	20	55	0	29	1	2	0	28
166	2	51	35	1	8	11	1	15	41	0	27	10	1	52	38
167	2	39	40	1	3	29	1	10	24	0	25	18	1	44	47
168	2	27	40	0	58	44	1	5	6	0	23	25	1	36	52
169	2	15	37	0	53	58	0	59	47	0	21	31	1	28	56
170	2	3	30	0	49	10	0	54	26	0	19	37	1	20	58
171	1	51	20	0	44	21	0	49	4	0	17	42	1	12	58
172	1	39	7	0	39	30	0	43	40	0	15	46	1	4	56
173	1	26	51	0	34	38	0	38	16	0	13	49	0	56	53
174	1	14	33	0	29	44	0	32	50	0	11	52	0	48	48
175	1	2	12	0	24	49	0	27	24	0	9	55	0	40	43
176	0	49	49	0	19	53	0	21	56	0	7	57	0	32	36
177	0	37	24	0	14	56	0	16	28	0	5	58	0	24	28
178	0	24	58	0	9	58	0	10	59	0	3	59	0	16	19
179	0	12	29	0	5	0	0	5	30	0	2	0	0	8	10
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note:
(1) In the above table, the first column headed by Anom, is the manda kendra i.e. the anomaly of a mean planet from its apogee (mandocca)
(2)D, M. S stand respectively for Degrees, Minutes and Seconds of arc.
(3)In the computations, variable periheries of the epicycles are adopted.

APPENDIX 3

Bhāskara I's Approximation for Sine

"I briefly state the rule (for finding the bhujaphala, koṭiphala etc.) without making use of the Rsine differences 225 (makhi) etc.

"Substract the degrees of the bhuja (or koṭi) from the degrees of half-a-circle (i.e., 180°). Then multiply the remainder by the degrees of the bhuja (or koṭi) and put down the result at two places. At one place substract the result from 40,500. By one-fourth of the remainder (thus obtained) divide the result at the other place as multiplied by the antyaphala (i.e. the epicyclic radius). Thus is obtained, the entire bāhuphala (or koṭiphala) for the sun, moon or the star-planets. So also are obtained the direct and inverse Rsines."

– MBh. VII, 17-19

In his Mahābhāskarīyam (MBh.), Bhāsakara I has given an interesting approximate formula for calculating Rsine of an acute angle without using the table. His formula, cancelling the constant, R, is

$$\sin\theta = \frac{4(180^\circ - \theta)\theta}{[40500 - (180^\circ - \theta)\theta]} \qquad (1)$$

where θ is in degrees.

Note: Bhāskara I's formula is valid for any angle from 0° to 360°. If A is any such angle, take θ equal to A or (180°-A) or (A-180°) or (360°-A) according as A is in I or II or III or IV quadrant.

Now, if θ is in radians, the above formula takes the form

$$\sin\theta = \frac{16\theta(\pi - \theta)}{[5\pi^2 - 4\theta(\pi - \theta)]}$$

Rationale for Bhāskara's formula

The following is a rationale, due to Prof. K.S. Shukla, of this approximate formula: In Fig. 1, let CA be the diameter of a circle of radius, R, where arc AB is equal to θ degrees and BD = R sin θ, Then

Area of triangle ABC = 1/2 AB.BC.

Also, area of triangle ABC = 1/2 AC.BD

Therefore,

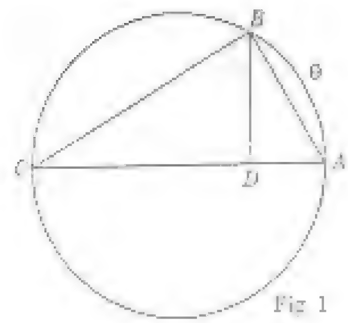

Fig 1

$$\frac{1}{BD} = \frac{AC}{AB.BC}$$

so that

$$\frac{1}{BD} > \frac{AC}{(\text{arc } AB) \times (\text{arc } BC)}$$

Let $\dfrac{1}{BD} = \dfrac{x.AC}{(\text{arc } AB \times (\text{arc } BC)} + y$

$$= \frac{2xR}{\theta(180-\theta)} + y$$

so that $R\sin\theta = \dfrac{\theta(180-\theta)}{2xR + \theta(180-\theta)y}$ (2)

Putting θ = 30° in (2), we get

$$\frac{1}{2}R = \frac{30 \times 150}{2xR + 30 \times 150y}$$

i.e., $2xR + 4500\,y = \dfrac{9000}{R}$ (3)

Putting q = 90° in (2), we have

$2xR + 8100y = \dfrac{8100}{R}$ (4)

From (3) and (4) we get

$$y = -\frac{1}{4R} \text{ and } 2xR = \frac{40500}{4R}.$$

Therefore from (2) we have

$$R\sin\theta = \frac{4\theta(180-\theta)R}{40500-\theta(180-\theta)}$$

which is the required result (1) with a constant factor R in the numerator and in the denominator.

Note: Both Āryabhaṭa I and Bhāskara I have taken R = 3438′.

In fact, 1 radian = $\dfrac{180}{\pi} \approx \dfrac{180}{3.1416}$

= 57°17'.7468 = 3438′ = R

The sine values according to Bhāskara I's of formula (1) are compared with the actual values (obtainable from calculators or tables) correct to 3 decimal places for angles from 0° to 90° at intervals of 10° in Table 1.

Table 1. Bhāskara's sine values of angles

Angle	sin A		Angle	sin A	
A	Bhāskara's	Actual	A	Bhāskara's	Actual
0°	0.000	0.000	50°	0.765	0.766
10°	0.175	0.174	60°	0.865	0.866
20°	0..343	0.342	70°	0.939	0.940
30°	0.500	0.500	80°	0.985	0.985
40°	0.642	0.643	90°	1.000	1.000

We see from Table 1 that the values from Bhāskara's approximation formula (1) are the same as the actual ones upto the second decimal place. Only in the third decimal place there is an error only by one digit +0.001. This error is insignificant in the type of further computations involved.

Formula (1) has been extnesively used by later Indian mathematicians and astronomers. In fact, the popular astronomer Gaṇeśa Daivajña (15th cent.) composed his famours text Grahalāghavam completely dispensing with sine and cosine using formula (1).

In the history of the world mathematics Bhāskara I gets the credit of being the first to give such a simple and good rational approximation formula for the sine of an angle A in terms of A as early as about fourteen centuries ago.

APPENDIX 4

Intervals of Rising of Sāyana Rāśis (or SIGNS)

According to the Grahalāghavam the durations of the rising of the sāyana Meṣa, Vṛṣabha and Mithuna at Laṅkā (on the equator) are, respectively, 278, 299 and 323 vināḍīs. These, diminshed by the vināḍīs of the local ascensional differences, are the durations of the risings of these three rāṣis at one's own place.

The figures written in the reverse order increased by the ascensional differences (cara), are the durations of the risings of the next three signs at the observer's place. We have

sin (cara) = $\tan\phi \tan\delta$

where ϕ is the latitude of the place and δ the declination corresponding to the ending of the rāśi, viz., for longitudes $\lambda_1 = 30^\circ$, $\lambda_2 = 60^\circ$ and $\lambda_3 = 90^\circ$. Also, with latitude $\beta = 0$ (for the points on the ecliptic), we have

$\sin\delta = \sin\lambda \sin\varepsilon$ ($\varepsilon = 24^\circ$)

Now, for $\lambda_1 = 30^\circ$, $\lambda_2 = 60^\circ$ and $\lambda_3 = 90^\circ$, with the obliquity of the eclipse e beign taken as 24°, we get the corresponding values of the declination:

$\delta_1 = \sin^{-1} [\sin 30^\circ \sin 24^\circ] = 11.734^\circ$

$\delta_2 = \sin^{-1} [\sin 60^\circ \sin 24^\circ] = 20.624646^\circ$

$\delta_3 = \sin^{-1} [\sin 90^\circ \sin 24^\circ] = 24^\circ$

The tabular differences of cara (ascensional difference) for a place of latitude ϕ, are given by the successive differences of

$R \tan\phi = \tan\delta$ (asus)

where 1 vināḍīka = 6 asus

Therefore, corresponding to the declinations δ_i of the ending of the first 3 rāśis, the tabular differences of cara, are given by the successive difference of

$(R \tan\phi \tan\delta_i)/6$ (vināḍīkas)

Thus, for example, for Chennai or Bangalore ($\phi \approx 13^\circ$), we have the tabular differnces given by the successive differences of

(i) $\tan 13^\circ (\tan 11.734^\circ) \times 3438/6 = 27.5$ vin.

(ii) tan 13° (tan 20.625°) × 3438/6 = 49.79 vin.

(iii) tan 13° (tan 24°) × 3438/6 = 58.90 vin.

Therefore, the tabular differences of the cara for the first three rāśis at Chennai (or Bangalore) are respectviely, 27.5, (49.79-27.5), (58.9-49.79) i.e.,

27.5, 22.29 and 9.11 vināḍīs.

The durations of the risings of the twelve rāśis at Chennai (or Bangalore) calculated according to the Grahalāghavam are given in the following Table.

Table: Durations of risings of rāśis at Chennai or Bangalore (ϕ = 13°)

Rāsi	Durations of risings at Laṅkā (vinādis)	Ascensional difference (tabular diff.)	Durations of rising at Chennai or Bangalore (vināḍīs)
Meṣa	278	-27.5	250.5
Vṛṣabha	299	-22.29	276.71
Mithuna	323	-9.11	313.89
Karkaṭaka	323	+9.11	332.11
Simha	299	+22.29	321.99
Kanyā	278	+27.5	305.5
Tulā	278	+27.5	305.5
Vṛścika	299	+22.29	321.29
Dhanus	323	+9.11	332.11
Makara	323	-9.11	313.89
Kumbha	299	-22.29	276.71
Mīna	278	-27.5	250.5

Note: (1) The tabular differences are additive for the rāśis from Karkaṭaka (λ = 90°) to the end of Dhanus (λ = 270°), and negative otherwise. (2) The total of the durations of risings fo all the twelve rāśis is 60 nādīs.

The Udayamānas of rāśis for a place on the earth's equator (latitude ϕ = 0°) can be obtained from the expression

$$\tan \alpha_i = \cos \in \tan \lambda_i$$

where α_i is the right ascension corresponding to the (tropical) celestial longitude λ_i and $\in$ is the obliquity of the ecliptic.

Now taking the traditional value $\in$ = 24° and λ_1= 30°, λ_2 = 60° and λ_3 = 90°, we have the corresponding right-ascension α_i (i = 1, 2, 3) : α_1 = 27°48', α_2 = 57°42' and α_3 = 90°. Therefore, the angular udayamānas of the first three rāśis are:

(i) Meṣa: $27^{\circ}48' = 1668'$

(ii) Vṛṣbha ϕ: $57^{\circ}42' - 27^{\circ}48' = 29^{\circ}54' = 17^{\circ}94'$

(iii) Mithuna : $90^{\circ} - 57^{\circ}42' = 32^{\circ}18' = 1938'$

Dividing the above by 6 we get the same in time units as 278, 299 and 323 vināḍīs.

APPENDIX 5: Sanskrit Text
Srī Gaṇeśadaivajña Viracitam
GRAHALĀGHAVAM

1. *Madhyamādhikāraḥ*

maṅgalācaraṇam :

jyōtiḥ prabodhajananī pariśōdhya cittaṃ
tatsūkta karmacaraṇair gahanārthapūrṇā |
svalpākśarā'pi ca tadaṃśākṛtairupāyair
vyaktīkṛtā jayati keśavavāk śrutiśca ||1||

paribhagnasamaurvikeśacāpam
dṛḍhaguṇahāralasat suvṛttabāhu |
suphalapradam āttanṛuprabhaṃ tat
smara rāmaṃ karaṇaṃ ca viṣṇurūpam ||2||

prayojanam :

yadyapyakārṣururavaḥ karaṇāni dhīrās
teṣu jyakādhanurapāsya na siddhirasmāt |
jyācāpakarmarahitaṃ sulaghuprakāraṃ
kartum grahaprakaraṇaṃ sphuṭamudyato'smi ||3||

ahargaṇasādhanam :

dvyabdhīndronitaśaka īśahṛt phalaṃ syāc
cakrākhyaṃ ravihataśeṣakaṃ tu yuktam |
caitrādyaiḥ pṛthagamutaḥ sadṛgghnacakrād
digyuktādamaraphalādhimāsayuktam ||4||

khatrighnaṃ gatatithiyuṅniragracakrāṅga
aṃśāḍhyaṃ pṛthagamuto'bbdhi ṣaṭkalabdhaiḥ |
ūnāhairviyutam ahargaṇo bhavedvai
vāraḥ syāccharahatacakrayuggaṇo'bjāt ||5||

***grahāṇām dhruvāḥ* :**

khavidhutānabhavāstaraṇerdhruvaḥ khamanalā rasavārdhaya īśvarāḥ |
sitaruco bhamukho'tha khagā yamau śarakṛtā gadito vidhutuṅgajaḥ ||6||

śailā dvau khaśarā agoḥ kṣitibhuvo bhūtattvadantā vidaḥ |
kendrasyābdhiguṇoḍavaḥ suraguroḥ khaṃ ṣaḍyamā vasvilāḥ ||
drākkendrasya bhṛgoḥ kuśakrayamalā rāśyādiko'tho śaneḥ |
śailāḥ pañcabhuvo yamābdhaya ime'tha kṣepakaḥ kathyate ||7||

***kṣepakāḥ* :**

rudrā gobjāḥ kuvedāstapana iha vidhau śūlino gobhuvaḥ ṣaṭ |
tuṅge'kṣātyaṣṭi devāstamasi khamuḍavo'ṣṭāgnayo'tho mahīje ||
dik śailāṣṭau jñakendre vibhakalanavabhaṃ pūjite'dryaśvibhūpāḥ |
śaukre kendre gṛhādyo'drinakhanava śanau gotithisvargatulyaḥ |8||

***ahargaṇotpanna grahe samskāravidhiḥ* :**

dinagaṇabhava kheṭaścakranighnadhruvono
divasakṛdudaye svakṣepayuṅmadhyamaḥ syāt |
nijanijapurarekhāntaḥ sthitādyojanaughād
rasalavamitaliptāḥ svarṇamindau pare prāk ||9||

***ravibudhaśukrāṇām sādhanam* :**

svakhanagalavahīno dyuvrajo'rkajñaśukrāḥ
khatithihṛtagaṇono liptikāsvaṃśakādyāḥ |
gaṇamanuhatirinduḥ svādribhūbhāgahīnaḥ
khamanuhṛtagaṇono liptikāsvaṃśapūrvaḥ ||10||

***candroccarāhvorānayanam* :**

navahṛtadinasaṅghaścandratuṅgaṃ lavādyaṃ |
bhavati khanagabhaktadyuvrajopeta liptam |
navakubhiriṣuvedairghasrasaṅghād dvidhāptāt
phalalavakalikaikyaṃ syādaguścakraśuddhaḥ ||11||

kujasya budhakendrasya cānayanam **:**

digghno dvidhā dinagaṇoṅkakubhistriśailair
bhaktaḥ phalāṃśakakalāvivaraṃ kujaḥ syāt |
trighno gaṇaḥ svavasudṛglavayugjña śīghra-
kendraṃ lavādyahiguṇā'ptagaṇonaliptam ||12||

guroḥ śukrakendrasya cānayanam **:**

dyupiṇḍo'rkabhakto lavādyo guruḥ syād
dyupiṇḍāt khaśailāptaliptāvihīnaḥ |
trinighnād dyupiṇḍād dvidhā'kṣaiḥ kvibhābjair
avāptāṃśayogo bhṛgorāśukendram ||13||

śanisādhanam **:**

khāganyuddhṛto dinagaṇo'ṃśamukhaḥ śaniḥ syāt
ṣaṭpañcabhūhṛtagaṇāt phalaliptikāḍhyaḥ ||13 ½||

grahāṇām madhyamagatiḥ **:**

go'kṣā gajā ravigatiḥ śaśino'bhrago'śvāḥ
pañcāgnayo'tha ṣaḍilābdhaya uccabhuktiḥ ||14||
rāhostrayaṃ kuśaśino'sṛja induramās
tarkā'śvino jñacalakendrajavo'ryahikṣmāḥ |
liptā jinā vikalikāśca guroḥ śarāḥ khaṃ
śukrāśukendragatiradriguṇāḥ śanerdve ||15||

sauro'rko'pi vidhūccamaṅkakaliko nābjo gurustvāryajo
'sṛgrāhū ca kajaṃ jñakendrakamathārye seṣubhāgaḥ śaniḥ |
śaukraṃ kendramajārya madhyagamitīme yānti dṛktulyatāṃ
siddhaistairiha parvadharmanayasatkāryādikaṃ tvādiśet ||16||

2. *Ravicandra spaṣṭīkaraṇaṃ*

bhujakoṭyādīnāmānayam **:**

dostribhonaṃ tribhordhvam viśeṣyaṃ rasaiś
cakrato'ṅkādhikaṃ syād bhujonaṃ tribham |
koṭirekaikakaṃ tritribhaiḥ syāt padaṃ
sūryamandoccamaṣṭādrayo'ṃśā bhavet ||1||

sūryamandaphalānayanam :

mandoccaṃ grahavarjitaṃ nigaditaṃ kendraṃ tadākhyaṃ budhaiḥ
kendre syāt svamṛṇaṃ phalaṃ kriyatulādye'tho vidheyaṃ raveḥ |
kendraṃ tadbhujabhāga khecaralavonaghnā nakhāste pṛthak
tadgoṃśonanageṣubhiḥ parihṛtāste'ṃśādikaṃ syāt phalam||2||

candramandaphalānayanam :

vidhoḥ kendradorbhāgaṣaṣṭhonanighnāḥ
kharāmāḥ pṛthak tannakhāṃśonitaiśca |
rasākṣairhṛtāste lavādyaṃ phalaṃ syād
ravīndū sphuṭau saṃskṛtau staśca tābhyām ||3||

ravicandrayoḥ gatiphalānayanam :

kendrasya koṭilavakhāśvilavonanighnā
rudrā ravestrikuhṛtāḥ śaśino dvinighnāḥ |
svāṅgāṃśakena sahitāśca gatau dhanarṇaṃ
kendre kulīramṛgaṣatkagate sphuṭā sā ||4||

palabhājñānāc carakhaṇḍa jñānam :

meṣādige sāyanabhāgasūrye
dinārdhabhā yā palabhā bhavet sā|
triṣṭhā hatā syurdaśabhirbhujaṅgair
digbhiścarārdhāni guṇoddhṛtā'ntyā ||5||

caraphalasādhanam :

syāt sāyanoṣṇāṃśubhujarkṣasaṅkhya-
carārdhayogo lavabhogyaghātāt |
khāgnyāptiyuktastu caraṃ dhanarṇaṃ
tulājaṣaṭke tapane'nyathā'ste ||6||

caraphala samskāraḥ :

deyaṃ taccaramaruṇe viliptikāsu
madhyendau dviguṇanavoddhṛtaṃ kalāsu |
bhāptaṃ ca dyumaṇiphalaṃ lave'tha vedā
'bdhyabdhyūnaḥ kharasahṛtaḥ śako'yanāṃśāḥ ||7||

pañcāṅga sādhanam :

bhaktā vyarkavidhorlavā yamakubhiryātā tithiḥ syāt phalaṃ
śeṣaṃ yātamidaṃ harāt prapatitaṃ bhogyaṃ viliptāstayoḥ |
bhuktyorantarabhājitāśca ghaṭikā yātaiṣyakāḥ syuḥ kramāt
pūrvārdhe karaṇaṃ bavādgata tithirdvighnyadritaṣṭā bhavet ||8||

tat saikaṃ tvapare dale'tha śakuneḥ syuḥ kṛṣṇabhūtottarād
ardhāccātha vidhośca sārkasitagorliptāḥ khakhāṣṭo (800) *ddhṛtāḥ |*
yāte sto bhayutī kramādgaganaṣaṇṇighne gataiṣye tayor
indorbhuktihṛte javaikyavihṛte yātaiṣyanāḍyaḥ kramāt ||9||

3. *Pañcatārā spaṣṭīkaraṇādhikāraḥ*

bhaumasya śīghraphalāṅkāḥ :

khamaṣṭamaruto'dribhūbhuva udadhyagorvyo'ṣṭadṛg
dṛśo navanagāśvino'kṣadaśanāḥ śarāṅgāgnayaḥ |
guṇāṅkadahanāḥ khakhābdhaya ibhāṅga rāmāḥ kramān
navāmbudhidṛśo nabhaḥ kṣhitibhuvaścalāṅkā ibhe ||1||

budhasya śīghraphalāṅkāh :

khaṃ bhūkṛtāḥ kuvasavo'dribhavāḥ khatithyo
'ṣṭādrīndavo navanavakṣitayo'rkapakṣāḥ |
arkāśvinaḥ śarakhagakṣitayotayo'kṣatithyo
go'ṣṭau khamāśuphalajāḥ syurime vido'ṅkāḥ ||2||

guroḥ śīghrāṅkāḥ :

khaṃ tattvāni nagā'bdhayo'ṣṭaṣaṭkāḥ
pañcebhā gajakhecarā rasā'śāḥ |
nāgā'śā dvidiśo navāhayaḥ ṣaṭ
ṣaṣṭiḥ ṣaṭkaguṇā nabho guroḥ syuḥ ||3||

śukrasya śīghrāṅkāḥ :

khamagnyaṅgaistulyā rasayamabhuvaḥ ṣaṭkadhṛtayo
'risiddhāḥ pakṣābhrā'gnaya udadhinārācadahanāḥ |
dviśūnyodanvantaḥ khajaladhikṛtā bhūrasakṛtās
trivedodanvanto rasayamaguṇā khaṃ bhṛgujaneḥ ||4||

śaneḥ śīghrāṅkāḥ :

khamiṣukṣitayo gajāśvino go-
dahanā nagakṛtāḥ payodhibāṇāḥ |
dvirageṣumitā hutāśabāṇāḥ
śaravedāstriguṇā dhṛtiḥ khamārkeḥ ||5||

śīghraphalasādhanam :

bhaumā'rkījyavihīnamadhyamaraviḥ syāt svāśukendraṃ tu
vidbhṛgvoruktamidaṃ rasordhvam inabhācchuddhaṃ tadaṃśā dinaiḥ |
bhaktāḥ khādiphalakramādiha gatāṅko'sau kṣayarddhyā hatāc
cheṣādbāṇakulabdhihīnayugayaṃ dighṛllavādyaṃ phalam ||6||

mandāṅkāḥ mandakendrāśca :

khaṃ go'śvino'drimaruto'kṣagajā navāśāḥ
siddhendavaḥ khadahanakṣitayo'sṛjo'ṅkāḥ |
māndā budhasya khamināḥ kudṛśo'ṣṭapakṣā
devāḥ śarānalamitā rasavahnayaḥ syuḥ ||7||

khendrarkṣāṇi navāgnayohyudadhayo'kṣākṣā nagākṣā guroḥ
śukrasyā'bhrarasesaviśvamanavo dvirbāṇacandrāḥ kramāt |
khaṃ go'bjāḥ khakṛtāḥ khaṣaṇ naganagā go'ṣṭau trinandāḥ śaneḥ
śuddho'bdhyadri ṣaḍgnināgagṛhataḥ syānmandakendraṃ kujāt ||8||

mandaphalānayanam :

mṛdukendrabhujāṃśakā dināptāḥ
phalamaṅkaḥ pragatastadūnitaiṣyaḥ |
pariśeṣahato dināptiyukto
daśabhaktaḥ phalamaṃśakādi māndam ||9||

grahe phalasamskāra vidhiḥ :

prāṅmadhyame calaphalasya dalaṃ vidadhyāt
tasmācca māndamakhilaṃ vidadhīta madhye |
drākkendrake'pi ca vilomamataśca śīghraṃ
sarvam ca tatra vidadhīta bhavet sphuṭo'sau ||10||

bhaumādīnām mandaspaṣṭā gatiḥ :

māndakāntaramārkyasṛggurūṇāṃ
bhaktaṃ bāṇanagaiḥ śaraiḥ kharāmaiḥ |
vidbhṛgvordvihatāśugoddhṛtaṃ tad
dadyāt prāgvaditau mṛdusphuṭā sā ||11||

bhaumādinām spaṣṭā gatiḥ **:**

bhaumāccalāṅkavivaraṃ śarahṛt svabāṇāṃ-
śāḍhyaṃ trihṛt kṛtahṛtaṃ dviguṇākṣabhaktam |
taddhīnayuk kṣayacaye tu mṛdusphuṭā syāt
spaṣṭā'tha ced bahuṝṇāt patitā tu vakrā ||12||

bhauma-śukrayoḥ vaiśiṣṭyam **:**

śukrārayoścalabhavo'ntyagato yadā'ṅkaḥ
śeṣāṃśakāśca patitāḥ pṛthagakṣabhūbhyaḥ |
ye'lpā bhṛgostrivihṛtā asṛjo'kṣabhaktā
deyāḥ svaśīghraphalavat sphuṭayoḥ sphuṭau tau ||13||

budha-śukra-bhaumānām gatiphale vaiśiṣṭyam **:**

kujabudhabhṛgujānāṃ ceccalāṅko'ntimaḥ syād
daśahatapariśeṣāṃśā nagādryagnibhaktāḥ |
phalamiṣudahanairyuk saptagobhistribāṇair
bhavati gatiphalaṃ tat syāt tadā naiva pūrvam ||14||

bhumādīnām vakra-mārga-kendrāmśāḥ **:**

trinṛpaiḥ śarajiṣṇubhiḥ śarārkair
nagabhūpaistribhavaiḥ kramāt kujādyāḥ
calakendralavaiḥ prayānti vakraṃ
bhagaṇāt taiḥ patitairvrajanti mārgam ||15||

bhauma-śanī-gurūṇām-udayāsta-kendrabhāgāḥ **:**

kṣitijo'ṣṭayamairudeti pūrve
gururindrai ravijastu saptacandraiḥ |
svasvodayabhāgasaṃvihīnair
bhagaṇāṃśair (360) *aparatra yānti cāstam* ||16||

bhudha-śukrayor-udayāsta-kendrāmśāḥ **:**

khaśariaśca jinaiḥ pare jñabhṛgvor
ūdayo'sto'kṣadinairnagādribhūbhiḥ |
udayo'kṣanakhaistryahīndubhiḥ prāg
asto digdahanaiśca ṣaṭsuraiḥ syāt ||17||

grahāṇām vakrodayādi-dina-jñānam :

vakrodayādigaditāṃśakato'dhikālpāḥ
kendrāṃśakāḥ kṣitisutād dviguṇāstribhaktāḥ |
sāṅkāṃśakā daśahatāṅgahṛtāḥ kubhaktā
vakrādyamāptadivasaiḥ krmaśo gataiṣyam ||18||

budha-śukrayor-vakrodayādīnām-dīnapramāṇam :

pūrvāstādudayaḥ pare'nṛjugatistoyāstamaindryudgamo
mārgo'sto'tra ca dantadantadahanāṣṭyājyāśadantairdinaiḥ |
cāndrestatparatatparaṃ tvatha bhṛgostadvaddvimāsyāttato
'ṣṭābhirvyaṅghribhuvāṅghriṇā vicaranaikenāṣṭamāsaiḥ kramāt ||19||

bhauma-guru-śanīnām-udayādi-dinapramāṇam :

bhaumasyāstādudayakuṭilarjutva mauḍhyaṃ kramāt syān
māsairvedairatha daśamitairlocanābhyāṃ ca digbhiḥ |
jīvasyorvyā sacaraṇayugaiḥ sāgaraiḥ sāṅghrivedaiḥ
sāṅghryaikena triyugadahanairardhayuktaistathā'rkeḥ ||20||

4. *Tripraśnādhikāraḥ*

laṅkodayamānena svodayamāna-sādhanam :

laṇkodayā vighaṭikā gajabhāni go'ṅka-
dasrāstripakṣadahanāḥ kramagotkramasthāḥ |
hīnānvitāścaradalaiḥ kramagotkramasthair
meṣādito ghaṭata utkramatastvime syuḥ ||1||

lagnānayanam :

tatkālārkaḥ sāyanaḥ svodayaghnā
bhogyāṃśāḥ khatryuddhṛtā bhogyakālaḥ |
evaṃ yātāṃśair bhavedyātakālo
bhogyaḥ śodhyo'bhīṣṭanāḍīpalebhyaḥ ||2||

tadanu jahīhi gṛhodayāṃśca śeṣaṃ
gaganaguṇaghnam aśuddhahṛllavādyam |
sahitam ajādigṛhairaśuddhapūrvair
bhavati vilagnamado'yanāṃśahīnam ||3||

iṣṭakāle lagnānayanam tasmādiṣṭakāla-ānayanañca :

bhogyato'lpeṣṭakālāt kharāmāhatāt
svodayāptāṃśayugbhāskaraḥ syāt tanuḥ |
arkabhogyastanorbhuktakālānvito
yuktamadhyodayo'bhīṣṭakālo bhavet ||4||

lagnānayane viśeṣaḥ :

yadi tanudinanāthāvekarāśau tadaṃśa
'ntarahata udayaḥ syāt khāgnihṛt tviṣṭakālaḥ |
inata udaya ūnaścet sa śodhyo dyurātrān
niśi tu sarasabhārkāt syāt tanūriṣṭakāle ||5||
golau staḥ saumyayāmyau kriyadhaṭarasabhe khecare'thāyane te
nakrāt kīṭācca ṣaḍbhe'tha carapalayutonāstu pañcendunāḍyaḥ |
ghasrārdhaṃ golayoḥ syāt tadayutakhaguṇāḥ syānniśārdhaṃ tathā'kṣac
chāyeṣughnyakṣabhāyāḥ kṛtidaśamalavonā yamāśāḥ palāṃśāḥ ||6||

natonnatau akṣakarnānayanam :

yātaḥ śeṣaḥ prākparatronnataḥ syāt
kālastenonaṃ dyukhaṇḍaṃ nataṃ syāt |
akṣacchāyāvargatattvāṃśayuktāḥ
mārtaṇḍāḥ syādaṇgulādyo'kṣa karṇaḥ ||7||

chāyārtham hārānayanam :

vedeśāḥ śarahṛccarāḍhyarahitāḥ saumyānudaggolayor
hāro'tho ghaṭikārdhayuṅnatakṛterdvyaṃśaḥ samākhyaḥ smṛtaḥ |
cet sārdhatrikuto nataṃ yadadhikaṃ vedāhataṃ tadviyuk
spaṣṭo'sau tadayugdharastvabhimataḥ syādakṣakarṇoddhṛtaḥ ||8||

digghnākṣabhāhṛtacaraṃ svaguṇaṃ dvinighnaṃ
sveṣvaṃśayugyugabhavānvitamatra bhājyaḥ|
karṇo'ṅgulādika iheṣṭaharāptabhājyaḥ
karṇārkavargavivarāt padamiṣṭabhā syāt ||9||

iṣṭacchāyāto natakālānayanam :

karṇaḥ syāt padamarkabhākṛtiyutestadbhakta bhājyo haro
'bhīṣṭastatpalakarṇaghātarahito madhyo haro dvyāhataḥ |
cedvedāṇkadharādhikaḥ pṛthagato vedāṇkabhūnādguṇā-
ptyāḍhyastasya padaṃ ghaṭīmukhanataṃ syādardhanāḍīviyuk ||10||

***sūkṣma krāntyānayanam* :**

catvārimśadaśītiradrikubhuvaḥ kvakṣendavo bhūdhṛtī
ṣaṭkhākṣīṇi jināśvino'ṅgavikṛtī khābdhyaśvinaḥ sāyanāt |
kheṭāddorlavadiglavapramagato'ṅko'sau tadūnāgatāc
cheṣaghnāddaśalabdhiyugdaśahṛto'mśādyo'pamaḥ syātsvadik ||11||

ṣaṭṣaḍiṣūdadhidṛkkubhirardhaiḥ
kheṭabhujāmśa dināmśamitaikyam |
śeṣahataiṣyadināmśayutaṃ vā
'mśādyapamaḥ sukhasamvyavahṛtyai ||12||

tato dalāni śodhayet tithighnaśeṣameṣyahṛt |
tithighnaśuddhasaṅkhyayā yutaṃ bhavanti dorlavāḥ ||13||

***dinamānādeva sthūla krānti prasādhanam* :**

dyudalatithiviyogastadvināḍyaścaraṃ syād
atha nijagajabhāgopetamakṣaprabhāptam |
dinakṛdapamabhāgāstattvaliptāyutāḥ syur
dyudalakṛśapṛthutve te kramādyāmyasaumyāḥ ||14||

krāntyakṣajasamskṛtirnatāmśāstaddhīnā navatiḥ syurunnatāmśāḥ |
dinamadhyabhavāstato'pi ye syuḥ krāntyaṃśā laghukhaṇḍakaiḥ parākhyaḥ ||15||

navatiguṇitamiṣṭamunnataṃ dyudalahṛtaṃ phalabhagato'pamaḥ |
kathitaparaguṇastaduddhṛtā ravinavaṣaṭ śravaṇo'thavā bhavet ||16||

***karṇād iṣṭonnatakālaṃ* :**

taraṇinavarasāḥ śravoddhṛtāḥ paravihṛtā apamo bhavettataḥ |
dinadalaguṇitā bhujāmśakā navatihṛtā athaveṣṭamunnatam ||17||

***yantrajonnatāmśebhya unnatakālaṃ* :**

abhimatayantralavāstato'pamo'sau
jinanighnaḥ parahṛttato bhujāmśāḥ |
dyudalaghnāḥ khanavoddhṛtāḥ kapāle
prāk paścādghaṭikāḥ kramādgataiṣyāḥ ||18||

unnatakālād yantrāmśāḥ **:**

khāṅkaghnonnataghaṭikā dinārdhbhakttā
bhāgāḥ syustadapamajāmśakāḥ paraghnāḥ |
siddhāptā nigaditavattato bhujāmśās
tatkāle syuriti ca yantrajonnatāṃśāḥ ||19||

yantrāmśāt karṇaḥ **:**

yantralavotthakrāntilavāptā vasvibhadasrāḥ (288) *syādiha karṇaḥ* |
karṇahṛtāste syādapamo'to bāhulavāḥ syuryantralavā vā ||20|

diksādhanam **:**

vṛtte samabhūgate tu kendrasthitaśaṅkoḥ kramaśo viśatyapaiti |
chāyāgramihā'parā ca pūrvā tābhyāṃ siddhatimerudak ca yāmyā ||21||

bhujadiśoḥ sādhanam **:**

vā'rkakrāntilavākṣakarṇanihatirbhākarṇanighnī nabho
akṣāgnyāptā ravidigbhujo yamadiśādvighnākṣabhāsaskṛtaḥ |
kendre bhotthavṛtau sa pūrṇaguṇavadbhāgrāt pradeyo bhaved
yāmyodak sa bhujārdhakendranihitā rajjustu pūrvāparā ||22||

digjñānārtham digamśānayanam **:**

dyumānakhaguṇāntaraṃ śivaguṇaṃ dine'lpādhike
hyapāgudagathā' nudagbhavati yantrabhāgāpamaḥ |
vasughnyubhayasamskṛtirnavati yantrabhāgāntarod
bhavāpamahṛtā tato bhujalavā digamśāḥ smṛtāḥ ||23||

digamśebhyo diksādhanam **:**

samabhuvi nihite turīyayantre
spṛśati yathā ca digaṃśakāgrakendre |
avalamba vibhota kendrasamsthe-
ṣīkābhā'tha diṣo'tra yantragāḥ syuḥ ||24||

nalikābandhanārtham bhujakoṭyānayanam **:**

krāntiḥ sphuṭābhimatakarṇaguṇā'kṣakarṇa
nighnī khakhādri (700) *hṛdapakramadigbhujaḥ syāt* |
samskārito yamadiśā'kṣabhayā sphuṭo'sau
tadvargabhākṛtiviyoga padaṃ ca koṭiḥ ||25||

nalikābandhanam **:**

jñātvā"śāḥ parakhecare paramukhīṃ prākkhecare prāṇmukhīṃ
bindoḥ koṭimato bhujaṃ svadiśi tanmadhye prabhāṃ vinyaset |
bindorbhāgragaśaṅku mastakagate sūtre nale khe khagaṃ
ke bindusthanarāgrabhāgrakagate sūtre nale lokayet ||26||

5. *Candragrahaṇādhikāraḥ*

gatagamyadināhatadyubhukteḥ kharasāptāṃśaviyugyuto grahaḥ syāt|
tatkālabhavastathā ghaṭīghnyāḥ kharasairlabdhakalonasamyutaḥ syāt ||1||

grahaṇa niścayam śarasādhanañca **:**

evaṃ parvānte virāhvarkabāhor
indrālpāṃśāḥ sambhavaśced grahasya |
te'ṃśā nighnāḥ śaṅkaraiḥ śailabhaktā
vyagvarkāśaḥ syāt pṛṣatko'ṅgulādiḥ ||2||

ravi-candra-bhūbhā bimbasādhanam **:**

vyasuśaragatīṣvaṃśo digyugbhavedvapuruṣṇagor
atha sitaruco bimbaṃ bhuktiryugācalabhājitā |
tadapi himagorbimbaṃ trighnaṃ nijeśalavānvitaṃ
vivasu bhavati kṣmābhābimbaṃ kilāṅgulapūrvakam||3||

mānaikyakhaṇḍagrāsayor ānayanam **:**

chādayatyarkamindurvidhuṃ bhūmibhā
chādakacchādyamānaikyakhaṇḍaṃ kuru |
taccharonaṃ bhavecchannametadyadā
grāhyahīnāvaśiṣṭaṃ tu khacchannakam ||4||

sthiti-marda-kālānayanam **:**

mānaikyakhaṇḍamiṣuṇā sahitaṃ daṣaghnaṃ
channāhataṃ padamataḥ svarasāṃśahīnam |
glaubimbahṛt sthitiriyaṃ ghaṭikādikā syān
mardaṃ tathā tanudalāntarakhagrahābhyām ||5||

sparśa-mokṣa-sthithi mardānayanam **:**

yugmāhatairvyagubhujāmśasamaiḥ palaiḥ sā
dviṣṭhā sthitirvirahitā sahitā'rkaṣaḍbhāt |
ūne vyagāvitarathā'bhayadhike sthitī staḥ
sparśāntime kramagate ca tathaiva marde ||6||

sparsādi kālānayanam **:**

tithiviratirayaṃ grahasya madhyaḥ
sa ca rahitaḥ sahito nijasthitibhyām |
grahaṇamukhavirāmayostu kālāv
iti pihitā'pihite svamardakābhyām ||7||

iṣṭagrāsānayanam **:**

pihitahateṣṭaṃ sthitivihṛtaṃ tat |
sacaraṇabhūyug grasanamabhīṣṭam ||8||

ayanavalanam **:**

tribhayutonaraviḥ svavidhugrahe 'yanalavāḍhya itaścaravddalaiḥ |
nagaśarendumitairvalanaṃ bhavet svaravidik tvatha madhyanatācca yat ||9||

akṣavalanānayanam **:**

viṣayalabdhagṛhādita uktavad valanamakṣahṛtam palabhāhatam |
udagapāgiha pūrvapare kramādrasahṛtobhaya samskṛtiraṅghrayaḥ ||10||

grāsadikacaranādyānayanam **:**

mānaikyārdhahṛtāt khaṣaḍghna pihitānmūlaṃ tadāśāṅghrayaḥ
khacchannaṃ sadalaikayuk ca gaditāḥ khacchannajāśāṅghrayaḥ |
savyā'savyamapāgudagvalanajāśāṅghrīn pradadyāccharā-
śāyāḥ syādgrahamadhyamanyadiśi khagrāso'thavā śeṣakam ||11||

sparśamokṣādi digjnānam **:**

madhyācchannāśāṅghribhiḥ prāk ca paścād
indorvyastaṃ tūśṇagoḥ sparśamokṣau |
khagrastāt khacchannapādaiḥ pare prāg
dattairindormīlanonmīlane staḥ ||12||

6. *Sūryyagrahaṇādhikāraḥ*

lambana sādhanam **:**

laganaṃ darśānte tribonaṃ pṛthaksthaṃ
tat krāntyamśaiḥ samskṛto'kṣo natāmśāḥ |
tad dvidy(22)*amśo vargitaśced dvikordhvo*
'dho'sau dvayūnaḥ khaṇḍitastadyutaḥ saḥ ||1||

sārko hāraḥ syāt tribhonodayārka-
viśleṣāṃśāśāṃśahīnaghnaśakrāḥ |
hārāptāḥ syāllambanaṃ nāḍikādyaṃ
tithyāṃ svarṇam vitribhe'rkādhikone ||2||

vyagau lambana samskāraḥ **:**

trikunighnavilambanaṃ kalāstatsahitonastithivadvyaguḥ śaro'taḥ |
atha ṣaḍguṇalambanaṃ lavāstairyugayugvitribhataḥ punarnatāṃśāḥ ||3||

nati sādhanam śara sādhanañca **:**

daśahṛtanatabhāgonāhatāṣṭendavastad
rahitasadhṛtiliptaiḥ ṣaḍbhirāptāsta eva |
svadigiti natiretatsaṃskṛtaḥ so'ṅgulādiḥ
sphuṭa iṣuramuto'tra syāt sthiticchannapūrvam ||4||

sparśamokṣa kālasādhanam **:**

sthitirasahatiramśā vitribhaṃ taiḥ pṛthaksthaṃ
rahitasahitamābhyāṃ lambane ye tu tābhyām |
sthitivirahitayuktaḥ samskṛto madhyadarśaḥ
kramaśa iti bhavetāṃ sparśamuktyostu kālau||5||

sammīlanonmīlana kālādi **:**

mardādevaṃ mīlanonmīlane sto grāso nādeśyo'ṅgulālpo ravīndvoḥ |
dhūmraḥ kṛṣṇaḥ piṅgalo'lpārdhasarvagrastaścandro'rkastu kṛṣṇaḥ sadaiva ||6||

iṣṭagrāsānayanam **:**

iṣṭaṃ dvighnaṃ channakṣuṇṇaṃ sparśāntyāntarnāḍībhaktam |
rūpārdhenopetaṃ vidyādiṣṭe kāle'rkasya grāsam ||7||

7. *Māsagaṇādhikāraḥ*

atha māsagaṇāt sulaghukriyayā
grahaṇadvayasiddhikṛte'bhidadhe |
sphuṭasūryavipātatithīñca vapur
grasanādi viśeṣacamatkṛtaye ||1||

kṣepakāḥ :

kṣepo bhādyaḥ khaṃ kṛtā bhūdṛso'rke
rudrāḥ sailā nāgacandrā vipāte |
vṛtte śūnyaṃ vajtriṇaścandrabāṇā
vārādye dvau vyaṅghrinandābdhayaḥ syāt ||2||

dhruvāḥ :

bhānoḥ khaṃ bhūḥ khābdhayo'yaṃ dhruvaḥ syāc
chailāḥ kvarkā rāśipūrvo vyagoḥ syāt |
vṛttasyāṅkā bhūrasāścātha tithyāḥ
vārādyasyākṣāḥ khagāstarkarāmāḥ ||3||

māsagaṇāt ravivipātau :

māsaughato dviguṇitānnagaṣaḍbhirāpta-
rāśyādinā rahitamāsagaṇo raviḥ syāt |
māsā gṛhāṇi vinijatrilavāśca te'mśā
māśāṅghritulyakalikāḥ syurayaṃ vipātaḥ ||4||

candrakendra vārādika sādhanam :

svādrayaṃśakena rahitā manutaṣṭamāsā
vṛttaṃ gaṇābhrakulavāḍhyalavaṃ gṛhādi |
svārdhānvitā dinamukhaṃ manutaṣṭamāsā
māsaughato daśaguṇadbhaguṇāptiyuktam||5||

dhruva-kṣepayoḥ samskāraḥ :

māsagaṇājjanito ravirūnaścakrahata dhruvakeṇa nijena |
saṅkalitā itare'tha ca te syuḥ kṣepayutā nijamāsi sitānte ||6||

pākṣika cālanam **:**

ravau pākṣikaṃ cālanaṃ khendradevā
vipāte nabho bāṇacandrā nakhāśca
ṣaḍarkā yugākṣā gṛhādyaṃ ca vṛtte
dinādye nabho'kṣābdhayo bāṇabāṇāḥ ||7||

ārdhavārṣika cālanam **:**

śarā vedapakṣā bhujaṅgāgnayo'rke vyagau ṣaṭkṛtāḥ kuśca ṣāṇmāsikaṃ syāt|
śarā vārdhayastrīṣavo bhādi vṛtte dinādye titherdvau bhavā
bhūrdinādyam||8||

iṣṭa tithyānayanam **:**

abhimata tithisiddhyai prāk pare yāstu tithyaḥ
svayugarasalavonāścālanaṃ syāddinādye |
svayugaguṇalavonāḥ syāllavādyaṃ dineśe
svaguṇanavalavonā viśvanighnāśca vṛtte ||9||

ravicandrayor mandaphala sādhanam **:**

atyaṣṭyaṣṭivṛṣārkagośaradṛśaḥ khaṇḍāni tairvṛttador
bhāgatrīndulavapramaikyamagataghnocchiṣṭaviśvāṃśayuk |
prāgvat syāt svamṛṇaṃ phalaṃ tviti raveḥ kendrādyadanyacca tad
dvyāptaṃ svāṅgalavonitaṃ kuru tayoḥ kāryā punaḥ saṃskṛtiḥ ||10||

hāra sādhanam **:**

vṛttaiṣyadalādrasāptiyuktā rahitāḥ karkimṛgādike ca vṛtte |
saguṇāṃśakhavahnayo haraḥ syādatha sūryāccarapūrvamuktavat syāt ||11||

tithi spaṣṭīkaraṇam **:**

nāḍyaḥ syuḥ phalasaṃskṛtirdaśahatā hāroddhṛtā'tho caraṃ
sāyaṃ lakṣaṇakaṃ tvatho vighaṭikāḥ paścādṛṇaṃ prāgdhanam|
svāṅghryūnāntarayojanānyatha tithiḥ spaṣṭā tribhiḥ saṃskṛtā
tatsaṃskāraghaṭīsamāśca kalikā deyā vyagau coṣṇagau||12||

sūrya vyagvoḥ sphuṭī karaṇam **:**

sasvārhallavaminajaṃ phalaṃ yugaghnaṃ
liptāstāḥ kuru ca tayoḥ sphuṭau ca tau staḥ |
vitryamśadviyutaharaḥ kṛśānubhaktaś
candrasya prabhavati bimabamaṅgulādyam ||13||

ravibhūbhābimba sādhanam **:**

khābdhyāptārkāgatadalayutonāḥ svakendre kulīra-
nakrādye syādvyarilavabhavā aṅgulādyarkabimbaṃ |
hāro vīṣuḥ svatithilavayuk syāt kubhā'syāṃ dhanarṇaṃ
khākṣāptārkāgatadalamato nakrakarkyādikendre ||14||

grahaṇa sambhava jñānam **:**

jñātvaivaṃ tithipūrvakaṃ grahaṇajaṃ śeṣaṃ bhavet pūrvavat
ṣaṇmāsairuta pakṣavarjitayutaiḥ pakṣe'thavā"lokayet |
arkendugrahaṇaṃ vyagorbhujalavaistithyalpakairuṣṇagor
yāmyairvasvadharair dyurātrigatithau cāharniśāmāśrite ||15||

grāsa sādhanam **:**

satryaṃśaguṇonito haro'yaṃ vedaghno'ṅkahṛto vyagorbhujāṃśaiḥ |
hīno bhavatāḍito'drihṛt syācchannaṃ śītaruco'ṅgulādikaṃ vā ||16||

sūryagrahaṇe sthūlagrāsa sādhanam **:**

amāntanatanāḍikāṅghrirahitādyutāt prāk pare
gṛhādikaraver natāṃśaka rasāṃśa saṃskāritāḥ |
vyagorbhujalavāḥ sphuṭāḥ syuratha saptaśuddhāśca te
nijārdhasahitā raveḥ sthagitamaṅgulādyaṃ sphuṭam ||17||

grahaṇa praveśa sādhanam **:**

vyagumadhyaparyayagaṇo dviguṇo vaṇigādige vyagugṛhe kuyutaḥ|
smṛtacakrasaṃjñakayuto vidhito gataparvapo munihṛtorvaritaḥ||18||

sūryacandrādi sādhanam **:**

tithiravihatiraṃśāstadyuto'rko vidhuḥ syād
atha jina(24)*guṇahāro dvyaṅgayuk tadgatiḥ syāt*|
khacaraśarakalāḥ syāt sūryabhuktistataḥ syur
bhayutijagatagamyā nāḍikāstithyapāyāt ||19||

8. *Grahaṇadvayasādhanādhikāraḥ*

pañcāṅgāt grahaṇa dvaya sādhanam **:**

atha vā'yaṃ tithipatrato'vagamyaḥ parvāntaśca ravistamastithervā |
bhasyetaiṣyaghaṭīyutirdyumānaṃ tebhyo'tha grahaṇadvayaṃ pravacmi ||1||

tārāṣaḍ vyagatithiyātagamya nāḍīyogāptā vyaguravidorlavonitāste |
saṃyuktā nijadalabhūpabhāgakābhyāṃ channaṃ
vā'ṅgulavadanaṃbhavetsudhāṃśoḥ ||2||

***candra bhūbhā bimbayor ānayanam* :**

aṅgayuktithighaṭīhṛtabāṇāṅkartavo'ṅgulamukhaṃ vidhubimbam |
digviyuktithighaṭīhṛtadṛgdṛktrīndavo'ṅgulamukhā kṣitibhā syāt ||3||

***candra grāsa sādhanam* :**

vidaśoḍughaṭīhṛtāḥ khabhūṣaḍvyagubhāsvadbhujabhāgavarjitāste |
śitikaṇṭhahatāsturaṅgabhaktāḥ sthagitaṃ cāṅgulapūrvakaṃ vidhoḥ syāt
||4||

***nakṣatraghaṭībhyaś candra bhūbhābimbayor ānayanaṃ* :**

bhagatāgatanāḍikaikyabhaktā navavedartava indubimbamuktam |
vimanūḍughaṭīhṛtāḥ śarākṣadvibhuvaḥ syāt kṣitibhā'ṅ gulādikā vā ||5||

***sūryagrahaṇe grāsa sādhanam* :**

khātyaṣṭayastithighaṭīvihṛtāḥ savedā
vā'thoḍunāḍihṛtadevayamāḥ sarāmāḥ |
hīnā vyagusphuṭalavairbhavasaṅguṇāste
śailoddhṛtāḥ khararucaḥ sthagitāṅgulāni ||6||

ravilavayutabhānordolavatryaṃśatulyair
virasalavamaheśā vyaṅgulairhīnayuktāḥ |
ajadhaṭarasabhe'rke bimbamasyāṅgulādyaṃ
sthitimukhamavaśiṣṭaṃ pūrvavat śeṣamatra||7||

9. *Udayāstādhikāraḥ*

***śukla pratipadi candra darsāna sambhavāsambhavam* :**

sārkāṃśāviha kuru pakṣatikṣaye'rkavyagvarkau caramatha kevalādvyagoryat |
ṣaḍbāṇairvihṛtamidaṃ kramāllavādyaṃ svarṇaṃ syādvyaguravigolayoḥ
pṛthak tat ||1||

tribhāyanalavānvitā'rūṇacarāhataṃ dvyakṣabhā-
hateḥ kṛtihṛtaṃ dhanarṇamasamaikagole vyagoḥ |
khakhānalaviśeṣitaḥ sarasabhāyanārkodayaḥ
śaradvikrahṛto dhanādhanamanalpakālpodaye ||2||

dyumitipratipadgamāntaraṃ yaccharabhaktaṃ svamṛṇaṃ dine'dhikone |
dhanamatra catuṣkasaṃskṛtiścet tapanāste vidhurīkṣyate'nyathā na ||3||

guror udayāsta sādhanam :
cakrāḍhyo madhuvaktramāsanicayo viśvāptacakronito
dvighno yuk daśamāsadhūrjaṭidinairbhaiḥ śeṣito bhacyutaḥ |
dvyāptaḥ syādbhamukhaḥ pṛthak tithilavairūno'sya bāhvaṃśakā
'rkāptāṃṣonayuto dhaṭājarasabhe māsādikaḥ syānmadhoḥ ||4||

tithidinarahitāḍhyo'sau dvidhā taiśca māsaiḥ
kramaśa iha bhavetāṃ mantriṇo'stodayau ca |

śukrodayāsta kālasādhanam :
atha madhumukhamāsāḥ saptabhūnighnacakraiḥ
svaśarayuga(45)*lavāḍhyaiḥ saṃyutā mārgaṇaghnāḥ* ||5||

udadhirasasametāś chidrakhegāmitaṣṭā
navanavapariśuddhāḥ pañcabhaktāḥ pṛthaksthāḥ|
rasaguṇadinahīnāḍhyā dvidhā caitratastair
bhṛgujaharidigastāmbūdayau staḥ krameṇa ||6||
navamāsabhaghlastrato'lpapuṣṭāḥ
pṛthaksthāḥ kramaśastu tairyutonāḥ
dvedhā yugavāsaronayuktās
toyāstaindryudayau kramādbhṛgoḥ staḥ ||7||

pūrvayuktyā niṣpanna guruśukra kāla sādhanam :
māsairnakhairvyaridinairudayāstakālaḥ
śukrasya śudhyati guroryadi sārdhaviśvaiḥ |
so'nyo bhavenmadhumukhādatha tairyutaścet
syāt tatparo'tha purato'pi vilomaśuddhyā ||8||

candra sthūla śara sādhanam :

prathame vyagucandradorgṛhe'ṃśāḥ
svadalāḍhyāstvapare nagābdhiyuktāḥ |
carame dalitā nagādriyuktā
vyaguvidhudig viśikho'ṅgulādikaḥ syāt ||9||

khaṇḍaiḥ sūkṣma śara sādhanam :

nṛpatithimanuviśvarudrago'dri
śrutivasudhā (16|15|14|13|11|9|7|4|1) *śarakhaṇḍakāni tairyat* |
vyaguvidhubhujato'pamoktivadvā
vyaguvidhudigviśikho'ṅgulādikaḥ syāt ||10||

laghugo'lpa inādudeti pūrve bhūyān bhūrigatirgrahaḥ pratīcyām |
bhūyām̐llaghugaḥ paratra cāstaṃ prācyāṃ bhūrijavo laghuḥ prayāti ||11||

grahodayāsta nimittam kālāmśāḥ :

bhāskarā nagabhuvo guṇacandrā bhūbhuvo divisadastithayo'bjāt |
prāktanairnigaditāḥ samayāṃśā vakriṇorbhṛguvidoḥ kṣitihīnāḥ ||12||

kujādīnām pātāmśāḥ :

khāmbudhayaḥ khayamāḥ khabhujaṅgāḥ khāṅgamitāḥ khadaśa kramaśaḥ syuḥ |
pātalavāḥ kusutādbudhabhṛgvormadhyamacañcalakendravihīnāḥ ||13||

graha śīghrakarṇa sādhanam :

kudvitryabdhiyugāśvino dalacayaścet ṣaḍbhapuṣṭaṃ calaṃ
kendraṃ cakraviśuddhamasya bhamitārdhaikyaṃ lavaghnāgatāt |
triṃśallabdhayutaṃ kujātkuyamalābdhīndvadribhaktaṃ kramāt
taddhīnā dhṛtiriṣvilā guṇabhuvo go'bjā inā drākśrutiḥ ||14||

kujādīnām śara sādhanam :

mandaspaṣṭakhagāt svapātarahitāt krāntyaṃśakāḥ kevalāt
karṇāptāstriyamāhatā atha guroścellocanāptāḥ punaḥ |
svāṅghryūnā asṛjo'ṅgulādikaśaraḥ pātonadik syādasau
trighnaḥ syāt kalikādikaḥ sphuṭatarastatsaṃskṛtaścāpamaḥ ||15||

pañcāṅgāt śara sādhanārtham mandaspaṣṭagrahaḥ **:**

vakrāstādyaṃ tithipaṭagataṃ taddine'syoktakendraṃ
syāt taccālyaṃ tvabhimatadine svāśukendroktagatyā|
tasmāt prāgvaccalaphalamidaṃ cālitaspaṣṭakheṭe
vyastaṃ deyaṃ mṛdujaphalabhāk syāt tato vā śarādyam ||16||

dṛkkarmārtham natāṃśāḥ **:**

prāk tribheṇa varjitāt saṃyutāt tu paścime |
kheṭato'pamākṣayoḥ saṃskṛtirnatā lavāḥ ||17||

dṛkkarma sādhanam **:**

ṣaṭśailāṣṭanavārkadhṛtyaditijāḥ khaṇḍāni kāryaṃ natāṃ-
śāśāṃśa pramakhaṇḍakaikyamagatocchiṣṭāṃśaghātād yutam |
āśāptyā ravihṛccharāṅgulahataṃ liptā grahe tā natāṃ-
śeṣvoḥ svarṇamabhinnabhinnadiśi sa vyastaṃ pare dṛggrahaḥ ||18||

udayāstayoḥ kālajñānam **:**

kalpyo'lpo ravirarkadṛkkhacarayoranyaśca lagnaṃ tayor
madhye syurghaṭikāśca pūrvavadimāḥ paścāt sacakrārdhayoḥ |
ṣaḍghnyaḥ kālalavā amībhiradhikairgamyo'sta ūnairgataḥ
proktebhyo'bhyadhikairgataḥ samudayo'pyūnaistu gamyo bhavet ||19||

divasānayanam **:**

khābhrāgnibhirvinihatāḥ kathiteṣṭakāla-
bhāgāntarasya kalikā ravibhodayāptāḥ |
tatsaptamena parato'tha javāntarāptā
yogena vakriṇi dinānyudayāstayoḥ syuḥ ||20||

candraśukrayor udayāstayor antaram **:**

syāt khābhrāgnyudayāntaraṃ bhavihṛtaṃ svarṇaṃ pṛthūnodaye
yat tatsaṃskṛtadṛṣṭikarmalavataḥ prāṇāṃśasaṃskāritāḥ |
pūrvoktā bhṛgucandrayoḥ kṣaṇalavāḥ spaṣṭā bhṛgośconitā|
dvābhyāṃ tairudayāstadṛṣṭisamatā syāllakṣitaiṣā mayā ||21||

agastyodayāsta sādhanam **:**

palabhā'ṣṭavadhonasaṃyutā gajaśailā vasukhecarā lavāḥ|
iha tāvati bhāskare kramādghaṭajo'staṃ hyudayaṃ ca gacchati ||22||

***graha nityodayāsta sādhanam* :**

khecaro'rkāstakāle saṣaḍbhārkato
yo'dhiko'lpo'rkato niśyudetīha saḥ |
astametyanyathā yo vidheyaḥ kramāt
pūrvapaścātsthadṛkkarmabhāk sa grahaḥ ||23||

***udayāstakāle rātrigata ghaṭī jñānam* :**

udgame yātakālaḥ khagāt tvastake
ṣaḍbhayuktāt saṣaḍ bhārkabhogyānvitaḥ |
yuktamadhyodayo'syodgamāste bhaved
rātriyāto'tha tatkālakheṭāt sphuṭaḥ ||24||

***candrasya asakṛt prakārārtham viśeṣatā* :**

indostu gopalāḍhyonaḥ kāryo'tha pratināḍikam|
yuto dvidvipalaiḥ spaṣṭaḥ kiṃ syāt tātkālikendunā ||25||

10. *Grahacchāyādhikāraḥ*

***grahāṇām dṛśyādṛaśyatva jñānam* :**

prāgdṛṣṭikarmakhacarastanuto'lpako'stāt
puṣṭaśca dṛśya iha khecarabhogyakālaḥ |
lagnena yuk ca vivarodayayugdyuyātaḥ
syāt khecarasya sitagoryadi gopalonaḥ ||1||

***grahāṇām chāyā sādhanam* :**

jināpto'kṣābhāghno'ṅgulamayaśaro'nena tu caraṃ
sphuṭaṃ saṃskṛtyāto dinamatha khagasya dyuvigatāt |
prabhādyaṃ saṃsidhyedatha khacarabhādarniśi gataṃ
bruve'thārādīnāṃ dyutiparigamaṃ yantravaśataḥ ||2||

***dhīyantreṇa chāyā jñānam* :**

paśyejjalādau pratibimbitaṃ vā kheṭaṃ dṛgauccyaṃ gaṇayecca lambam |
tallambapātapratibimbamadhyaṃ dṛgauccyahṛt sūryahataṃ prabhā syāt ||3||

***grahāṇām dyugata kālajñānam* :**

jñātvā'numānānniśi yātanāḍīstatkālakheṭāt kathitaiścarādyaiḥ |
dṛṣṭaprabhāderdyugato grahasya sādhyastvihendoryadi gopalāḍhyaḥ ||4||

grahodaya dinaśeṣa rātrigatakāla sādhanam **:**

prāgdṛkkhacarāṅgabhāḍhyabhānvoralpo 'rkastvaparastanustadantaḥ |
kālaḥ sa khagodaye dyuśeṣo ratrītaḥ kramaśo grahe'lpapuṣṭe ||5||

sūryāstād rātrigata kālajñānam **:**

tenono'tha ca sahito grahadyuyātaḥ
syādarkāstamayakato niśi prayātaḥ |
ced glāvo'numitaghaṭīṣvato'lpapuṣṭaṃ
dvighnaṃ tatsamapalayug viyuk sphuṭaḥ saḥ ||6||

11. *Nakṣatracchāyādhikāraḥ*

nakṣatra dhruva jñānam **:**

dāsrādaṣṭa ca mūrcchanā gajaguṇā nandābdhayo dṛgrasāḥ
ṣaṭtarkā yugakhecarā rasadiśo'dryāśā navārkāḥ kramāt |
bhāgyādaṣṭayugendavo'kṣatithayaḥ khātyaṣṭayo'ṃśā dhruvās
trayaṣṭābjā gajagobhuvo ravidṛśaḥ siddhaśvinaḥ khatridṛk ||1||

mūlāt syurdvijināḥ śarāśugadṛśaḥ kvaṅgāśvino'ṣṭeṣudṛk
bāṇarkṣāṇi rasāṣṭadṛk nakhaguṇāstattvāgnayo'śvāmarāḥ |
khaṃ dattāyanadṛkkriyāḥ syuriha ca kṣepo'kṣabhāghno'rkahṛt
svarṇaṃ prāk parato'nyathottara śare te syuḥ svadeśe dhruvāḥ ||2||

nakṣatrāṇām śaralavāḥ **:**

diksūryeṣviṣudik śivāṅgakhanagābhrārkāśca viśve bhavās
tvāṣṭrād dvau nagavahnayaḥ kuyamalāgnībhākṣabāṇā dviṣaṭ |
karṇāt triṃśadaritrayaḥ khajinabhābhraṃ tvāṣṭrahastāhibhe
dvīśāt ṣaṭsu kabhāt traye śaralavā yāmyā udak śeṣabhe ||3||

prajāpatyādi tārakāṇām dhruva śarāmśāḥ **:**

prajāpatibrahmahṛdagnyagastyāpāṃvatsalubdhadhruvakāṃśakāḥ syuḥ |
kuṣaṭ ṣaḍakṣāstriśarā nabho'ṣṭau tryaṣṭendavo bhūphaṇinaḥ krameṇa ||4||

teṣāṃ kramādgośikhinaḥ kharāmā aṣṭau rasāśvāḥ śikhinaḥ khavadāḥ |
śarāṃśakāḥ syurmunilubdhayostu yāmyāstu saumyāḥ pariśeṣakāṇām ||5||

nakṣatra dhruvāt chāyāsādhanam **:**

nijadeśabhavāddhruvācca bāṇācchāyā yantralavādi kheṭavat syāt |
chāyāderapi ceha rātriyātaṃ nakṣatragrahayoga uktavacca ||6||

grahasya rohiṇī śakaṭa bheda lakṣaṇam **:**

gavi nagakulave(17)*khago'sya cedyamadigiṣuḥ kha śarāṅgulādhikaḥ* |
kabhaśakaṭamasau bhinattyasṛk śaniruḍupo yadi cejjanakṣayaḥ ||7||

candrasya śakaṭabheda kālaḥ **:**

svarbhānāvaditibhato'ṣṭa ṛkṣasaṃsthe
śītāṃśuḥ kabhaśakaṭaṃ sadā bhinatti |
bhaumārkyoḥ śakaṭabhidā yugāntare syāt
sedānīṃ na hi bhavatīdṛśi svapāte ||8||

khamadhyastha nakṣatreṇa rātrigatakālaḥ **:**

khamadhyagarkṣadhruvataḥ sphuṭaṃ caraṃ
tato dinārdhānnijabhodayaistanuḥ |
bhavet tadā lagnamatho tadaṅgabhā-
nvitārkamadhye ghaṭikā niśāgatāḥ ||9||

udayāsta nakṣatrābhyām rātrigata kālaḥ **:**

udyadbhadhruvakaḥ svadeśajo'staṃ vā prāpnuvataḥ saṣaḍgṛhaḥ |
syāt tatkālavilagnakaṃ tataḥ prāgvat syurghaṭikā niśāgatāḥ ||10||

svadeśa nakṣatrodayāni sthiralagnāni **:**

iti naijadeśapalabhāvaśato hyudayaṃ khamadhyamatha vā'stamayam |
vrajadaśvibhādiṣu sukhārthamiha sthiralagnakāni vidadhīta sudhīḥ ||11||

12. *Śṛṅgonnatyadhikāraḥ*

māsasya prathame'ntime'tha vā'ṅghrau
vidhuśṛṅgonnatirīkṣyate yadahni |
tapanāstamayodaye'vagamyāstithayaḥ
sāvayavāḥ kramādgataiṣyāḥ ||1||

valana śuklayoḥ sādhanam :

ravihatatithayo'mśāstadviyugyuk krameṇa
dyumaṇiraparapūrve māsapāde vidhuḥ syāt |
nṛpaguṇatithirūnā svaghnatithyākṣabhāghnī
śarakuhṛdudagāśā saṃskṛtārkāpamāmśaiḥ ||2||

candrasya ca vyastaśarāpamāmśair
dvinighnatithyā vihṛtā'ṅgulādyam |
samskāradikkaṃ valanaṃ sphuṭaṃ syāt
sveṣvamśahīnāstithayaḥ sitaṃ syāt ||3||

sṛṅgonnati dig jñānam :

unnataṃ valanāśāyāmanyasyāṃ syānntaṃ vidhoḥ |
valanasyāṅgulaiḥ śṛṅgaṃ kimatra parilekhataḥ ||4||

13. *Grahayutyadhikāraḥ*

bhaumādīnām bimba sādhanam :

pañcartvagāṅkaviśikhāḥ pṛthagīśakarṇā-
yogāhatāḥ prakṛtibhānvarisiddharāmaiḥ |
bhaktāḥ phalonasahitāḥ śravaṇe'dhikone
te tryuddhṛtāḥ syursṛjo vapuraṅgulāni ||1||

grahayuti gataiṣyatā sādhanam :

adhikajavakhage'dhike'lpabhukteratha kuṭile'lpatare'nulomato vā |
anṛjugakhagayostu śīghrage'lpe yutirnayoḥ pragatā'nyathā tu gamyā ||2||

grahayuti gataiṣya divasānām jñānam :

ṛjugatikhagayostu vakrayorvā vivarakalā gatijāntareṇa bhaktāḥ |
gatijayutihṛtā yadaikavakro yutirgatā pragatā'ptavāsaraiḥ syāt ||3||

cālyau kheṭau samau sto grahayutidivasaiścandrabāṇaḥ svanatyā |
saṃskāryo'tra grahau sveṣudiśi samadiśostvalpabāṇo'parasyām ||
ekānyāśau yadeṣū virahitasahitau kheṭamadhye'ntaraṃ syād |
bhedo mānaikyakhaṇḍādiha laghuni tadālpaṃ hi kiṃ lambanādyam ||4||

14. *Pātādhikāraḥ*

vyatīpāta vaidhṛtyor lakṣaṇam :

nandaghnāyanabhāgatulyaghaṭikonāḥ sārdhaviśve tathā
tārāstāvati sāgrayogavigame pāto vyatīpātakaḥ |
jñeyo vaidhṛtiratra yātaghaṭikāḥ sarvarkṣanāḍīhatāḥ
spaṣṭāḥ syuḥ śaraṣaḍhṛtā(65) *iha tamo'rko sāyanāṃśau kuru* ||1||

spaṣṭapāta sambhavatvam :

golaikye sāgvarkabhānvoḥ sadā syātpāto'nyatve cedraverbāhubhāgāḥ |
pañceṣubhyo(55)' *lpāstadāstyeva pātaḥ puṣṭāścet tatsaṃśayastaṃ ca bhidmaḥ* ||2||

khābhrendudvirasā dhṛtirnagaśarāḥ sāgvarkabhānvoḥ padai-
kye'rdhāni tryagarudrabhūpatinakhāstryakṣīṇi bhede kramāt |
kṣepaḥ ṣaḍdaśa (6|10)*cārkakoṭijalaveṣvaṃśapramārdhaikyakaṃ*
śeṣāṃśaiṣyavadheṣu bhāgasahitaṃ sandhirbhavet kṣepayuk ||3||

sāgvarkabhujāṃśakā yadālpāḥ sandheḥ krāntisamatvamasti cet|
adhikā na tadā bhujāṃśasandhyantarasādṛśyamihāpamāntaraṃ syāt ||4||

pātasya gataiṣya sādhanam :

pade yugmauje'rkaḥ samaviṣamagole satamasas
tadā yātaḥ pātastvagata itaratve nigaditāt |
vibhinne gole cediha kṛtaśarāṅghrer laghutarā
raverdorbhāgāḥ syādiha ravipadānyatvamucitam ||5||

śara khaṇḍāni śara sādhanam ca :

pañcadhā sāgarāḥ pañcadhā vahnayo dvau caturdhā kubhūkhābhramaṅkā
iṣoḥ | (4|4|4|4|4|3|3|3|3|3|2|2|2|2|1|1|0|0)
sāgvinād̄dorlaveśvaṃśatulyaikyakaṃ śeṣabhogyāhatīṣvaṃśayuk syāt śaraḥ ||6||

spaṣṭa śara sādhanam :

khaikādike ravibhujāṃśadaśāṃśake syād
dhāro'rkasūryamanudhṛtyuḍavo'ṅgarāmāḥ |

khāśvā dviśatyuḍuguṇāstu śarāddharāptyā
hīno'tra sa hyapamasaṃskṛtaye sphuṭaḥ syāt ||7||

krāntisādhanārtham aṅkāḥ :
caturdhā nakhā gobhuvo dvirgajābjā nṛpāṣṭīndraviśvārkadigvasvagākṣāḥ |
trayaḥ kṣmā'pamāṅkāḥ kramādarkabāhorlaveṣvaṃśa(5)*tulyo gato nyasya śeṣam* ||8||

ukta śarakrānti khaṇḍayoḥ spaṣṭīkaraṇam :
kramotkramāduktaśarāpamāṅkān saṅkhyāhi bhogyāt kramataḥ ṣaḍaṅkāḥ |
sthāpyā gataiṣyā gatagamyapāte yugme'thavauje syurime'yanāṃśāḥ ||9||

antyādvilomā yadi te'nyadikkā athāpamāṅkāḥ kramaśaḥ śarāṅkaiḥ |
susaṃskṛtāstrīnduhṛtāpamaiṣyāṅkenāpi te spaṣṭatarā bhaveyuḥ ||10||

pātamadhya kāla sādhanam :
prāk sthāpitāḥ śeṣalavāḥ śarāptā rūpād (1) *viśuddhā laghusaṃjñakaḥ syāt* |
ādyaḥ sphuṭāṅko laghunāhato yastenāḍhyabāṇāt kramaśo'tha jahyāt ||11||

tānaṅkān śeṣamaśuddhabhaktaṃ viśuddhasaṅkhyāsahitaṃ laghūnam |
trighnaṃ bhanāḍīghnamibhāptamāptayātaiṣyanāḍīṣviha pātamadhyam ||12||

pātasthiti kāla sādhanam :
aviśuddhahṛtā yamārka(122)*nāḍyaḥ prāk paścāt sthitiratra pātamadhyāt* |
śuddhāḥ kvacidatra cet ṣaḍaṅkāḥ saṃskāryāśca tadagratastrayo'ṅkāḥ ||13||

sūryāccandra sādhanam :
ṣaḍbhārkabhacyutaravistviha sāyanābjo
'thārke ghaṭīsamakalāścalanaṃ tvathendoḥ |
bhuktyaṃśakā bhaghaṭikāptakhakhāhayaḥ syus
taccālitāpamasamatvamiha pratītyai ||14||

15. *Pañcāṅga candragrahaṇānayanādhikāraḥ*

māsāḥ svārdhayutāstitherdinādyaṃ tāvatyo ghaṭikāśca māsasaṅghāt |
tryaṃśāḍhyāḥ sahitaṃ dvayatrayābhyāṃ cakraghnākṣanavāṅgavargayuktam ||1||

nakṣatra dhruvaka sādhanam **:**

khaṃ saptāṣṭayamā(0|7|28)*śca cakranighnā nāgāmbodhighaṭīyutā bhaśuddhāḥ* |
dvābhyāṃ dhūrjaṭibhirvinighnamāsairyuktā bhadhruvako bhapūrvakaḥ syāt ||2||

piṇḍa sādhanam **:**

svargāḥ śarā nava ca cakrahatā dvinighna-
māsānvitā dvihṛtamāsayutā ghaṭīṣu |
piṇḍo bhavedyugakubhiḥ khacaraiḥ sametas
taṣṭo gajāśvibhiridaṃ bhavatīha cakram ||3||

sūryanakṣatrād ghaṭīphalam **:**

śivadaśavasuṣaṭkābdhyaśvināḍyo'śvibhāt svaṃ
khaguṇaśaranagāṅkāśeśadigdiṅnavāṣṭau |
rasaguṇakhaminarkṣādāditeyādṛṇaṃ syur
dviyugarasagajāṅkāśeśvarā vaiśvataḥ svam ||4||

sūryanakṣatra jñānam **:**

vedaghneṣṭatithiryutārkabhāgā yojyā bhadhruvanāḍikāsu tat syāt |
sūryarkṣaṃ vigataṃ tato'rkajākhyanāḍīhīnyutaṃ sphuṭaṃ bhavet tat ||5||

piṇḍaphala sādhanam **:**

piṇḍe yuktatithau tadādyamanuṣu svaṃ śeṣapiṇḍeṣvṛṇaṃ
viśvendvośca śarā daśārkayamayoḥ pañcendavastrīśayoḥ |
gocandrā daśavedayoryamayamāḥ pañcāṅkayoḥ syurjināḥ
ṣaḍvasvośca nage tu tattvaghaṭikāḥ śakre ca khaṃ piṇḍajāḥ ||6||

sphuṭa-tithi-vārādika sādhanam **:**

vāreṣu tithirdeyā heyā nāḍīṣu jāyate madhyā |
ravijāpiṇḍaphalābhyāṃ susaṃskṛtā spaṣṭatāṃ yāti ||7||

nakṣatra sādhanam **:**

syādbhaṃ kevalayostithi dhruvabhayoryoge tithernāḍikā
yuktā vyaṅgalava dvinighnatithinā vyastārkajāḥ saṃskṛtāḥ |
nāḍībhirdhruvabhasya cenna viyutāstaddhīnaṣaṣṭyanvitāḥ
saikaṃ bhaṃ ghaṭikā viyat ṣaḍadhikāḥ ṣaṣṭyūnitā vyekabham ||8||

yoga sādhanam **:**

sūryabhendubhayutirbhavedyutistadghaṭīvivaramatra nāḍikāḥ|
ceddyubhe'lpaghaṭikāstadā sakuryogako'sya ghaṭikāḥ khaṣaṭ(60)*cyutāḥ* ||9||

pūrṇānte rāhu sādhanam **:**

cakrāhatāḥ sapta yamau khabāṇā (7|2|50)
māsāhatāḥ khaṃ kṣitirabdhirāmāḥ (0|1|34)
bhādyānyoḥ saṃyutirarka(12)*śuddhā*
bhāṃśair(27)*yutā śuklagame tamaḥ syāt* ||10||

sūrya sādhanaṃ grahaṇa sambhavañ ca:

vedaghna gohṛdravibhuktadhiṣṇyam tithyantajo'rko gṛhapūrvakaḥ saḥ |
rāhūnitaḥ parvaṇi tadbhujāṃśā manvalpakāśced grahasambhavaḥ syāt ||11||

grāsamāna sādhanam **:**

piṇḍānāḍyantarāṅghryūnayuktā ināḥ(12)
svarga(21)*piṇḍādri* (7) *pinḍāt kramādvarjitāḥ* |
vyagvināddorlavaiḥ svārdhayuktā bhavec
channamindo ravicchannakādyuktavat ||12||

candrabimba bhūbhā bimba sādhanam **:**

vitryaṃśeśāḥ piṇḍanāḍyantarasya
ṣaṣṭonāḍhyāḥ svargapiṇḍādripiṇḍāt |
glaubimbaṃ syāttadvadurvīprabhā syāt
trighnasyākṣāṃśonayuktāni bhāni ||13||

pratimāsa vārādi cālanaṃ **:**

vārādike bhūḥ kuguṇāḥ khabāṇāḥ (1|31|50)
piṇḍe dvayaṃ(2)*bhe dvayamīśanāḍyaḥ* (2|11)
kṣepyāḥ krameṇa pratimāsamatra
rāhau yugāṅkāḥ(94)*kalikā viyojyāḥ* ||14||

16. *Upasaṃhārādhikāraḥ*

1442 ***śakāt pūrvam ahargaṇa sādhanam :***

dvyābdhīndrāḥ śakarahitāstato bhavāptaṃ
cakrākhyaṃ ravihataśeṣakaṃ tu hīnam |
caitrādyaiḥ pṛthagamutaḥ sadṛgghnacakrāt
siddhāḍhyādamaraphalādhimāsayuktam ||1||

khatrighnaṃ tithirahitaṃ niragracakra
'ṅgāṃśāḍhyaṃ pṛthagamuto'bdhiṣaṭkalabdhaiḥ |
ūnāhairviyutamahargaṇo bhavedvai
vāraḥ prāk śarahata cakrayuggaṇo'bjāt ||2||

cakranighnadhruvopetāḥ svakṣepā dyugaṇodbhavaiḥ |
kheṭairūnāḥ syuriṣṭāhe dvayabdhīndrālpaḥ śako yadā ||3||

ātmanaḥ savinayatvam **:**

pūrve prauḍhatarāḥ kvacit kimapi yaccakrurdhanurjye vinā
te tenaiva mahātigarvakubhṛducchṛṅge'dhirohanti hi |
siddhāntoktamihākhilaṃ laghukṛtaṃ hitvā dhanurjye mayā
tadgarvo mayi māstu kiṃ na yadahaṃ tacchāstrato vṛddhadhīḥ ||4||

nandigrāma ihāparāntaviṣaye śiṣyādigītastutir
yo'bhūt kauśikavaṃśajaḥ sakalasacchāstrārthavit keśavaḥ |
sūnustasya tadaṅghripadmabhajanāllabdhvāvabodhāṃśakaṃ
spaṣṭaṃ vṛttavicitramalpakaraṇaṃ caitad gaṇeśo'karot ||5||

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